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ANALYSIS, OCCURRENCE AND FATE OF ORGANOTIN COMPOUNDS IN THE ENVIRONMENT

R. James Maguire

Environmental Contaminants Division
National Water Research Institute
Department of the Environment
Canada Centre for Inland Waters
Burlington, Ontario L7R 4A6
CANADA

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ABSTRACT

A review is presented of the analysis, occurrence and fate of organotin compounds in the environment.

The state of the art in analytical instrumentation is generally adequate, although there are few published methods on media other than water. The main classes of organotin compounds likely to be found in the Canadian environment are methyl-, butyl-, phenyl- and cyclohexyltin compounds, and most of these species can be analyzed satisfactorily using existing methods; however, it is desirable to have a method which features continuous introduction of high pressure liquid chromatographic eluent into a suitable detector for those compounds, or conjugates, which are not volatile.

There are few data on the occurrence of organotin compounds in the environment. Some of those that have been detected are very toxic to aquatic organisms.

Persistence studies on the major classes of organotin compounds have indicated that abiotic degradation generally occurs, as does biological degradation, through mechanisms of sequential dealkylation or dearylation. Adsorption to soils and sediments appears to be strong, although subsequent mobilization by biota cannot be ruled

out. In general, photolysis appears to be the rate-limiting degradative step. Methylation of tin and organotins, although a slow process, may nevertheless be significant with regard to transport of tin in and from aquatic environments. Further information on occurrence, persistence and fate of methyl-, butyl-, phenyl- and cyclohexyltin species is required before environmental and human health risk assessments can be made.

INTRODUCTION

Tin as a metal and in its chemical compounds has a wide variety of use. Characteristically, in many of its applications, only small amounts of tin are needed to see its effect. This is generally true for the organotin compounds which, during the past thirty years, have developed into important industrial commodities. A further characteristic of tin is that it is unsurpassed by any other metal in the multiplicity of its organic applications. These involve such widely divergent fields as stabilizers for polyvinyl chloride, industrial catalysts, industrial and agricultural biocides, and wood-preserving and antifouling agents, to mention only the most important applications.

The annual world consumption of tin in all forms was about 200 million kg in 1976, and of this total about 28 million kg was in the form of organotin compounds (Zuckerman *et al*. 1981). The U.S. consumption of organotin compounds was about 11 million kg in that year, and an 11 to 13% annual growth was predicted for the period 1978 to 1988. Comparable Canadian figures are not available.

The increasing annual use of organotin compounds, some of which are very toxic, caused organotin compounds as a class to be placed on the Department of the Environment's Environmental

Contaminants Act Category III list, which essentially meant that further information was required on their occurrence, persistence and toxicity in order to make environmental and human health risk assessments (Canada Department of Environment and Department of National Health and Welfare 1979). Since that time, the butyl- and methyltin series of compounds have been found in some Canadian waters and sediments (Maguire et al. 1982; Maguire 1984).

Acting independently of the Department of the Environment, the Subcommittee on Water of the Associate Committee on Scientific Criteria for Environmental Quality of the National Research Council of Canada has identified Organotin Compounds in the Aquatic Environment as a priority topic, and it is the intention of this committee to produce a "criteria document that will examine the critical scientific issues surrounding this topic and clarify the fundamental concepts on which criteria are based".

This review of the analytical methods for, and occurrence and fate of, organotin compounds in the environment is a contribution to the National Research Council review and it also constitutes part of an environmental risk assessment required by the Department of the Environment under the Toxic Chemicals Management Program.

This review does not cover all aspects of organotin compounds. Other aspects, including some earlier discussions on environmental chemistry, have been the subjects of several excellent reviews (Barnes and Stoner 1959; Ingham et al. 1960, Tobias 1966; Coates et al. 1967; Neumann 1970; Poller 1970; Sawyer 1971; Zuckerman 1976; Horwitz 1979; Piscator 1979; World Health Organization 1980; Negishi 1980; Davies and Smith 1980; Duncan 1980; Bock 1981; Zuckerman et al. 1981; Davies and Smith 1982).

ANALYTICAL METHODS

Table 1 describes analytical methods that have been used for inorganic tin and organotin compounds in a variety of media, with specific comments on methods where appropriate.

Compounds have generally been designated for convenience as cations since there is evidence that at least some organotin species in water exist as cations (e.g., Tobias 1966; Maguire et al. 1983a); where it is obvious that an ion is not involved (e.g., analysis of neat compound), then the relevant compound is noted. In addition, the figures in the column entitled "MDL" (minimum detectable level) should be regarded with caution since it is not yet common practice, however desirable, to distinguish "limit of detection" from "limit of

quantitation". In this regard, a good review, with guidelines, has been published (American Chemical Society Committee on Environmental Improvement and Subcommittee on Environmental Analytical Chemistry 1980).

It should be recognized that no single method will be best for all types of organotin compounds and inorganic tin. The older spectrophotometric methods have largely been supplanted by more sensitive techniques which employ chromatographic separation of different tin-containing species.

Gas chromatographic separation of organotin compounds has necessitated the preparation of suitably volatile analytes, and the preparation of hydride (R_nSnH_{4-n}) and alkyl ($R_nSnR'_{4-n}$) derivatives has predominated. Hydride derivatives are usually generated *in situ*, then swept into a cold trap or chromatographic column prior to elution into the detector; the advantage is that the volatile analyte can be evolved from its matrix, with attendant gains in sensitivity (e.g., Hodge *et al.* 1979). Alkyl derivatives are not prepared *in situ* and thus are usually subjected to "clean-up" steps prior to analysis. By such techniques, however, they can be greatly concentrated, facilitating analysis, and they are usually stable enough to be stored for long periods of time, unlike at least some hydrides (e.g., Soderquist and Crosby 1978). Plasma atomic emission detectors offer good

sensitivity (and of course multi-element capability); however the two most common detectors in the gas chromatographic trace analysis of organotin compounds are the flame photometric detector (FPD) and the quartz tube furnace atomic absorption spectrophotometer (AAS). The FPD offers truly outstanding sensitivity in those models which have glass internal surfaces (e.g., Aue and Flinn 1980); however the refractory combustion product SnO_2 may accumulate on internal surfaces, causing a decrease in detector sensitivity (e.g., Maguire and Tkacz 1983). The quartz tube furnace - AAS technique, introduced by Chu et al. (1972) for other purposes, has the advantages that fouled furnaces are disposable and that the technique may be used for many different volatile metals or organometals.

Liquid chromatographic separation of organotin compounds does not of course require the preparation of volatile analytes, and would in general be the method of choice for analysis of non-volatile or high molecular weight organotin compounds were it not for the fact that the development of sensitive detectors has been slower than in the field of gas chromatography. Jewett and Brinkman (1981, and references therein) have used a graphite furnace atomic absorption spectrophotometer as a detector for a high pressure liquid chromatograph (HPLC), but the connection is of necessity discontinuous, with attendant loss of sensitivity. Burns et al. (1981) have successfully coupled HPLC to a quartz tube furnace - AAS via a hydride genrator, in

the analysis of lower alkyltin species; however, it remains to be seen if this technique is successful with larger organotin molecules. One technique which may have promise is the coupling of a microbore HPLC to a flame photometric detector or a quartz tube furnace AAS. The small solvent flow rate (10 to 100 µL/min) in microbore HPLC has already been shown to be compatible with direct introduction to flame photometric and alkaline flame ionization detectors in the analysis of organophosphorus pesticides (McGuffin and Novotny 1981a, 1981b).

ENVIRONMENTAL OCCURRENCE OF ORGANOTIN COMPOUNDS

Table 2 describes the environmental occurrence of tin and organotin compounds. In general, contamination of the environment by inorganic tin is only slight; however, increased concentrations in some sediments have been correlated with increasing anthropogenic activity (e.g., Hallas and Cooney 1981; Goldberg et al. 1981). Byrd and Andreae (1982) have estimated that waste incineration contributes more tin to the atmosphere than all other combined anthropogenic and natural sources.

There have been few studies on the environmental occurrence of organotin compounds. Methyltin compounds have been detected in a

variety of waters (Braman and Tompkins 1979; Hodge et al. 1979; Byrd and Andreae 1982; Jackson et al. 1982; Maguire et al. 1982; Tugrul et al. 1983) and in sediment and aquatic biota (Tugrul et al. 1983). The environmental occurrence of methyltin compounds may be a result of anthropogenic input, or the result of biologically-mediated methylation of inorganic tin which may or may not be of anthropogenic origin. In addition to methyltin compounds, methyltin hydrides have been detected in some areas of Chesapeake Bay (Jackson et al. 1982).

The more toxic butyltin compounds have been detected at generally higher concentrations than the methyltin compounds in some waters (Hodge et al. 1979; Jackson et al. 1982; Maguire et al. 1982) and sediments (Seidel et al. 1980; Maguire 1984). The environmental occurrence of butyltin compounds is a result of anthropogenic input primarily through the use of tri-n-butyltin compounds as antifouling agents in marine paint. In Ontario, the occurrence of butyltin compounds is largely restricted to the water and sediments of harbours, marinas and other areas of heavy boating or shipping activity. In addition to butyltin compounds, butylmethyltin compounds have been detected in the sediments of some harbours in Ontario (Maguire 1984), and are probably the result of biologically-mediated methylation of anthropogenically-derived butyltin species.

ENVIRONMENTAL TRANSFORMATION AND FATE OF ORGANOTIN COMPOUNDS

The persistence and fate of any toxic substance in any environmental "compartment" is a function of the kinetics of a variety of routes of degradation and dissipation. From the aquatic point of view, some of the more important considerations, in addition to simple water flow, are basic properties such as aqueous solubility, vapour pressure and octanol-water partition coefficient, and such processes as hydrolysis (or stability in the dark), volatilization, sunlight photolysis, adsorption to suspended matter and to sediments, microbiological degradation or transformation and uptake by aquatic biota.

Before the literature is reviewed, there are a few points worth noting.

The persistence of any organotin compound should not be defined in terms of the time required for anion exchange; this gives a false impression of degradation kinetics when what is significant is a definition in terms of loss of alkyl or aryl groups, since the toxicity of organotins to most organisms decreases with decreasing number of organic substitutents at the tin atom.

The persistence of any toxic substance in a water-sediment system should not be solely defined in terms of adsorption to sediment

since toxic residues could be mobilized again through sediment resuspension, or could be taken up by benthic biota.

An important point to note with regard to photolysis is that although the use of Hg lamps in the laboratory yields much useful information on chemical mechanisms, the use of environmentally more relevant light sources (i.e., sunlight or appropriately filtered light of suitable intensity) will yield more reliable estimates for persistence vis-a-vis sunlight photolysis.

Some organotin species, and inorganic tin, under some conditions adsorb to Teflon and glass (Meinema et al. 1978; Maguire et al. 1983a); such adsorption may vitiate the findings of some workers.

For convenience, the discussion on the persistence and fate of tin and organotins will treat the compounds separately by class.

The Sn^{4+} oxidation state is thermodynamically more stable than Sn^{2+} and thus in most environmental compartments, with the exception of some anaerobic sediments, inorganic tin will likely be found in the Sn^{4+} state. Fanchiang and Wood (1981) have shown that the half-life for oxidation of Sn^{2+} to Sn^{4+} is about 2 d in oxygenated water at 23°C.

Several workers have shown that Sn^{4+} can be methylated in nutrient medium or natural water-sediment mixtures; $MeSn^{3+}$, Me_2Sn^{2+}, Me_3Sn^{+}, Me_4Sn and a methyltin hydride of unknown composition (but more volatile than Me_4Sn) have been variously identified as products. In only one case were yields given, and they were vanishingly small (≤0.008% - Chau et al. 1981); nevertheless, methylation of inorganic tin should not be discounted as a significant environmental phenomenon, since the process (i) can convert tin to more volatile forms capable of atmospheric redistribution, and (ii) can convert tin to more toxic forms. In this latter context, however, the toxicity difference between methyltin compounds and inorganic tin is not as great as that between methylmercury and inorganic mercury.

Methyltin species can also be further methylated in natural water-sediment systems. The process may be better described as being biologically mediated rather than solely biomethylation since, for example, Me_4Sn may result from disproportionation of lesser-methylated species (Guard et al. 1981), or of a methyltin hydride (Jackson et al. 1982). Methyltin compounds can also be sequentially demethylated to inorganic tin by photolysis (Blunden 1983), but an estimate of an "environmental half-life" is uncertain since light of wavelengths less than 290 nm (the lower limit for sunlight) was used. Estimated lower limits for these photolytic half-lives in water are 30 hr for Me_3Sn^{+}, 300 hr for Me_2Sn^{2+} and 1500 hr for $MeSn^{3+}$.

Neat Me_3SnOH (and the bis oxide) will react with atmospheric CO_2 to produce $(Me_3Sn)_2CO_3$; however, in water, Me_3Sn^+ will probably remain as the hydrated cation in the presence of dissolved CO_2. This comment is applicable to all those neat trialkyltin hydroxides or bis (trialkyltin) oxides which react with atmospheric CO_2 to yield carbonates.

Ethyltin species are dealkylated in mammals, but little reliable information is available on environmental persistence or fate; these comments are also applicable to propyl-, pentyl-, hexyl-, octyl- and mixed cyclohexylphenyltin compounds. These six classes of organotin compounds are either little-used or are not very toxic to most organisms.

The literature on butyltin compounds is, by contrast, fairly extensive. Butyltin species are sequentially dealkylayted by mammals, sheepshead minnows, one algal species and some fungal and bacterial cultures, although an attempt at degrading Bu_3Sn^+ by tin-tolerant bacteria from Chesapeake Bay was unsuccessful (Blair et al. 1982). The mechanism of dealkylation in mammals appears to involve carbon-hydroxylated intermediates. The maximum observed bioconcentration factor for Bu_3Sn^+ in whole sheepshead minnow was 2.6×10^3, and the depuration "first half-life" was 7 d.

The tributyltin species does not lose butyl groups in the dark, and does not volatilize, over a period of at least two months. There is equivocal evidence for its strong binding to soils and sediments; experimental complications include the formation of unextractable residues and microbial dealkylation. Soil-bound Bu_3Sn^+ should not be thought of as biologically unavailable; Gile et al. (1982) have presented some equivocal evidence for its uptake by earthworms. Estimates of the sunlight photolytic half-life of Bu_3Sn^+ vary from 18 to 89 d; indeed, statements on the aquatic environmental persistence of Bu_3Sn^+ rest on this difference in half-life of what is probably the rate limiting degradative process. Recoveries of products of Bu_3Sn^+ photolysis are generally poor. One reason for this, by analogy with phenyltin compounds, may be that water-soluble polymeric di- and monobutyltin compounds are formed. There has been a report of the occurrence of methylated derivatives of tri- and dibutyltin species which suggests that methylation may be a significant pathway of transformation of Bu_3Sn^+ in sediment-water systems.

There are fewer data on Bu_2Sn^{2+} and $BuSn^{3+}$; photolytic half-lives are generally of the same order as those for Bu_3Sn^+.

Tricylohexyltin degrades in vivo (mammals) through sequential loss of cyclohexyl groups; carbon-hydroxylated intermediates are involved. Photolysis on surfaces proceeds with an estimated "sunlight

half-life" of 8 d, and appears to proceed through sequential dealkylation. Volatilization from water is at least ten times slower. There is some evidence for strong binding to soil and dealkylation by soil microbes. Photolysis in water produces cyclohexane and cyclohexanol, indicating dealkylation, but half-lives are not available. The above statements are generally applicable to Cy_2Sn^{2+} and $CySn^{3+}$.

The triphenyltin species suffers sequential dearylation by mammals and bacteria. It appears to bind strongly to soil as evidenced by a 50% decrease in extractability over 40 d (Barnes et al. 1973). Sunlight photolysis on surfaces ($t_{\frac{1}{2}}$ ~14 d) and in water ($t_{\frac{1}{2}}$ 14 to 21 d) appears to proceed through sequential dearylation, although there is evidence for formation of water-soluble polymeric di- and monophenyltin species. The Ph_3Sn^+ species is stable in water in the dark for over a month, and is slowly degraded ($t_{\frac{1}{2}}$ ~140 d) by microbes in soil. At low concentrations, Ph_2Sn^{2+} and $PhSn^{3+}$ are much less stable in water ($t_{\frac{1}{2}}$ is several minutes for $PhSn^{3+}$ and 3 d for Ph_2Sn^{2+}), and there is evidence for formation of water-soluble polymeric tin species.

REFERENCES

Aldridge, W.N. and Street, B.W. 1981. Spectrophotometric and fluorimetric determination of tri- and di-organotin and -organolead compounds using dithizone and 3-hydroxyflavone. Analyst 106:60-68.

Alzieu, C., Thibaud, Y., Héral, M. and Boutier, B. 1980. Assessment of the hazards arising from the use of antifouling paints in mollusk-framing areas. Rev. Trav. Inst. Pêches marit. 44:301-348.

Alzieu, C., Héral, M., Thibaud, Y., Dardignac, M.-J. and Feuillet, M. 1982. Influence des peintures antisalissures à base d'organostanniques sur la calcification de la coquille de l'huitre Crassostrea gigas. Rev. Trav. Inst. Pêches marit. 45:101-116.

American Chemical Society Committee on Environmental Improvement and Subcommittee on Environmental Analytical Chemistry. 1980. Guidelines for data acquisition and data quality evaluation in environmental chemistry. Anal. Chem. 52:2242-2249.

Andreae, M.O. 1983. The determination of the chemical species of some of the "hydride elements" (Arsenic, Antimony, Tin and Germanium) in sea water: methodology and results. In "Trace Metals in Seawater", C.S. Wong, E. Boyle, K.W. Bruland, J.D. Burton and E.D. Goldberg, eds., Plenum Press, N.Y., pp. 1-19.

Andrews, S.B., Faller, J.W., Barrnett, R.J. and Mizuhira, V. 1978. Organometallic fatty acid and phospholipid analogs. Synthesis and incorporation and detection in model membranes and biomembranes. Biochim. Biophys. Acta 506:1-17.

Arakawa, Y., Wada, O., Yu, T.H. and Iwai, H. 1981a. Simultaneous determination of trialkyltin homologues in biological materials. J. Chromatogr. 216:209-217.

Arakawa, Y., Wada, O., Yu, T.H. and Iwai, H. 1981b. Rapid method for the determination of tetraalkyltin compounds in various kinds of biological material by gas chromatography. J. Chromatogr. 207:237-244.

Ashton, A., Fogg, A.G. and Burns, D.T. 1973. Applications of sensitized reactions. Spectrophotometric determination of tin in steel with catechol violet and cetyltrimethylammonium bromide. Analyst 98:202-208.

Aue, W.A. and Flinn, C.G. 1977. A photometric tin detector for gas chromatography. J. Chromatogr. 142:145-154.

Aue, W.A. and Flinn, C.G. 1980. Modification of a conventional flame photometric detector for increased tin response. Anal. Chem. 52:1537-1538.

Aue, W.A. and Hastings, C.R. 1973. Response of a filterless flame photometric detector to hetero-organics. J. Chromatogr. 87:232-235.

Aue, W.A. and Hill, H.H., Jr. 1972a. A tin-sensitive hydrogen flame detector. J. Chromatogr. 70:158-161.

Aue, W.A. and Hill, H.H., Jr. 1972b. A hydrogen-rich flame ionization detector sensitive to metals. J. Chromatogr. 74:319-324.

Aue, W.A. and Hill, H.H., Jr. 1973. Selective determination of hetero-organics by a dual-channel detector based on flame conductivity and emission. Anal. Chem. 45:729-732.

Barnes, R.D., Bull, A.T. and Poller, R.C. 1973. Studies on the persistence of the organotin fungicide Fentin Acetate (triphenyltin acetate) in the soil and on surface exposed to light. Pestic. Sci. 4:305-317.

Barnes, J.M. and Stoner, H.B. 1959. The toxicology of tin compounds. Pharmacol. Rev. 11:211-231.

Barug, D. 1981. Microbial degradation of bis(tributyltin) oxide. Chemosphere 10:1145-1154.

Barug, D. and Vonk, J.W. 1980. Studies on the degradation of bis (tributyltin) oxide in soil. Pestic. Sci. 11:77-82.

Basters, J., Martijn, A., Van der Molen, T., Pasma, P., Rabenort, B., van Rossum, B. and Smink, J. 1978. Gas liquid chromatographic method for determining Fentin in Fentin-Maneb preparations: CIPAC Inter-laboratory Study. J. Assoc. Off. Anal. Chem. 61:1507-1512.

Bennett, R.L. and Smith, H.A. 1959. Spectrophotometric determination of tin with phenylfluorone. Anal. Chem. 31:1441-1442.

Blair, E.H. 1975. Biodegradation of tricyclohexyltin hydroxide. In "IUPAC Third International Congress of Pesticide Chemistry", Helsinki, Finland, July 3-9, 1974; eds., F. Coulston and F. Korte. G. Thieme Publishers, Stuttgart, pp. 406-409.
[Environ. Qual. Saf. Suppl. 3:406-409].

Blair, W.R., Olson, G.J., Brinckman, F.E. and Iverson, W.P. 1982. Accumulation and fate of tri-n-butyltin cation in estuarine bacteria. Microb. Ecol. 8:241-251.

Blunden, S.J. 1983. The ultraviolet degradation of the methyltin chlorides in carbon tetrachloride and water. J. Organomet. Chem. 248:149-160.

Blunden, S.J. and Chapman, A.H. 1978. Fluorimetric determination of triphenyltin compounds in water. Analyst 103:1266-1269.

Bock, R. 1981. Triphenyltin compounds and their degradation products. Residue Rev. 79:1-270.

Boettner, E.A., Ball, G.L., Hollingsworth, Z., Aquino, R. 1981. Organic and organotin compounds leached from PVC and CPVC pipe. Report No. EPA-600/1-81-062, Health Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH, 45268, 102 pp.

Booth, M.D. and Fleet, B. 1970. Electrochemical behavior of triphenyltin compounds and their determination at submicrogram levels by anodic stripping voltammetry. Anal. Chem. 42:825-831.

Braman, R.S. and Tompkins, M.A. 1979. Separation and determination of nanogram amounts of inorganic tin and methyltin compounds in the environment. Anal. Chem. 51:12-19.

Brinckman, F.E., Blair, W.R., Jewett, K.L. and Iverson, W.P. 1977. Application of a liquid chromatograph coupled with a flameless atomic absorption detector for speciation of trace organometallic compounds. J. Chromatogr. Sci. 15:493-503.

Brinckman, F.E., Jackson, J.A., Blair, W.R., Olson, G.J. and Iverson, W.P. 1983. Ultratrace speciation and biogenesis of methyltin transport species in estuarine waters. In "Trace Metals in Sea Water", C.S. Wong, E. Boyle, K.W. Bruland, J.D. Burton and E.D. Goldberg (eds.), Plenum Press, N.Y., pp. 39-72.

Brooks, J.S., Clarkson, R.W., Allen, D.W., Mellor, M.T.J. and Williamson, A.G. 1982. A 119 m-Sn Mossbauer study of the photochemical degradation of organotin stabilized PVC. Polym. Degrad. Stabil. 4:359-363.

Brown, J.M., Chapman, A.C., Harper, R., Mowthorpe, D.J., Davies, A.G. and Smith, P.J. 1972. The characterization of triorganotin hydroxides and of bis(triorganotin) oxides by infrared and Mössbauer spectroscopy. J. Chem. Soc. (Dalton): 338-341.

Burns, D.T., Glockling, F. and Harriott, M. 1980. Comparative assessment of gas-liquid chromatography and high-performance liquid chromatography for the separation of tin tetralkyls and alkyltin halides. J. Chromatogr. 200:305-308.

Burns, D.T., Glockling, F. and Harriott, M. 1981. Investigation of the determination of tin tetraalkyls and alkyltin chlorides by atomic absorption spectrometry after separation by gas-liquid or high-performance liquid-liquid chromatography. Analyst 106:921-930.

Byrd, J.T. and Andreae, M.O. 1982. Tin and methyltin species in sea water: concentrations and fluxes. Science 218:565-569.

Callow, M.E., Millner, P.A. and Evans, L.V. 1979. Organotin resistance in green seaweeds. In "Proceedings of the International Seaweed Symposium", Vol. 9, (1977) A. Jensen and J.R. Stein, eds., Science Press, Princeton, N.J., pp. 191-197.

Canada Department of Environment and Department of National Health and Welfare. 1979. Environmental Contaminants Act. Priority Chemicals - 1979. In The Canada Gazette, Part 1, Dec. 1, pp. 7365-7370.

Casida, J.E., Kimmel, E.C., Holm, B. and Widmark, G. 1971. Oxidative dealkylation of tetra-, tri-, and dialkyltins and tetra- and trialkylleads by liver microsomes. Acta Chem. Scand. 25:1497-1499.

Chapman, A.H. and Price, J.W. 1972. Degradation of triphenyltin acetate by ultraviolet light. Intern. Pest Control 14:11-12.

Chau, Y.K., Wong, P.T.S. Kramar, O. and Bengert, G.A. 1981. Methylation of tin in the aquatic environment. In "International Conference on Heavy Metals in the Environment", Amsterdam, Sept. 1981, publ. by World Health Organization, pp. 641-644.

Chau, Y.K., Wong, P.T.S. and Bengert, G.A. 1982. Determination of methyltin (IV) and tin (IV) species in water by gas chromatography/ atomic absorption spectrophotometry. Anal. Chem 54:246-249.

Chu, R.C. Barron, G.P. and Baumgarner, P.A.W. 1972. Arsenic determination at sub-microgram levels by arsine evolution and flameless atomic absorption spectrophotometric technique. Anal. Chem. 44:1476-1479.

Clark, J.R. and Viets, J.C. 1980. Back-extraction of trace elements from organometallic-halide extracts for determination by flameless atomic absorption spectrometry. Anal. Chem. 53:65-70.

Coates, G.E., Green, M.L.H. and Wade, K. 1967. Organometallic compounds. Vol. I. The main group elements, 3rd. ed., Methuen and Co., Ltd., pp. 413-482.

Corbin, H.B. 1970. Separation and determination of trace amounts of tin present as organotin residues on fruits. J. Assoc. Off. Anal. Chem. 53:140-146.

Corbin, H.B. 1973. Rapid and selective pyrocatechol violet method for tin. Anal. Chem. 45:534-537.

Coyle, C.F. and White, C.E. 1957. Fluorometric determination of tin with flavonol. Anal. Chem. 29:1486-1488.

Davies, A.G. and Smith, P.J. 1980. Recent advances in organotin chemistry. Adv. Inorg. Chem. Radiochem. 23:1-77.

Davies, A.G. and Smith, P.J. 1982. Tin. Chapter 11 in "Comprehensive Organometallic Chemistry: The Synthesis, Reactions and Structures of Organometallic Compounds", G. Wilkinson, F.G.A. Stone and E.W. Abel, eds., Pergamon Press, N.Y., pp. 519-627.

Dizikes, L.J., Ridley, W.P. and Wood, J.M. 1978. A mechanism for the biomethylation of tin by reductive Co-C bond cleavage of alkylcobalamins. J. Amer. Chem. Soc. 100:1010-1012.

Dogan, S. and Haerdi, W. 1980. Determination of total tin in environmental biological and water samples by atomic absorption spectrometry with graphite furnace. Intern. J. Environ. Anal. Chem. 8:249-257.

Dressler, M., Martinu, V. and Janak, J. 1971. Response of the alkali flame ionization detector to silicon, tin and lead compounds. J. Chromatogr. 59:429-433.

Duncan, J. 1980. The toxicology of molluscicides. The organotins. Pharmac. Ther. 10:407-429.

Esposto, R., Camoni, I., Chiacchierini, E. and Magri, A. 1978. Determination of triphenyltin compounds and tricyclohexyltin hydroxide by gas chromatography of their derivatives. Annali di Chimica 68:235-245.

Estes, S.A., Poirier, C.A., Uden, P.C. and Barnes, R.M. 1980. Gas chromatography with plasma emission spectroscopic detection of Friedel-Crafts catalyzed alkyl group redistribution products among Si, Ge, Sn and Pb atoms. J. Chromatogr. 196:265-277.

Estes, S.A., Uden, P.C. and Barnes, R.M. 1982. Plasma emission spectral detection for high-resolution gas chromatographic study of group IV organometallic compounds. J. Chromatogr. 239:181-189.

Evans, W.H., Cardarelli, N.F. and Smith, D.J. 1979. Accumulation and excretion of [1-^{14}C] bis (tri-n-butyltin) oxide in mice. J. Toxicol. Environm. Health 5:871-877.

Evans, W.H., Jackson, F.J. and Dellar, D. 1976. Evaluation of a method for determination of total antimony, arsenic and tin in foodstuffs using measurement by atomic absorption spectrophotometry with atomization in a silica tube using the hydride generation technique. Analyst 104:16-34.

Everett, G.L., West, T.S. and Williams, R.W. 1974. The determination of tin by carbon filament atomic absorption spectrometry. Anal. Chim. Acta 70:291-298.

Fanchiang, Y.-T. and Wood, J.M. 1981. Alkylation of tin by alkylcobalamins. Kinetics and mechanism. J. Amer. Chem. Soc. 103:5100-5103.

Fano, V. and Zanotti, L. 1973. Trace determinations of tin (II) and tin (IV) in different solvents (H_2O, CH_3OH) by anodic stripping voltammetry. Microchem. J. 18:345-349.

Figge, K., Koch, J. and Lubba, H. 1977. Contribution to the gas chromatographic analysis of organo-tin stabilizers for polyvinyl chloride. J. Chromatogr. 131:317-327.

Filenko, O.F. and Isakova, E.F. 1979. Dynamics of the accumulation of triphenyltin chloride by Daphnia. Biol. Nauki (3):46-49.

Fish, R.H, Kimmel, E.C. and Casida, J.E. 1976. Bioorganotin chemistry: reactions of tributyltin derivatives with a cytochrome P-450 dependent monooxygenase enzyme system. J. Organomet. Chem. 118:41-54.

Fish, R.H., Casida, J.E. and Kimmel, E.C. 1977. Bioorganotin chemistry: situs and stereo-selectivity in the reaction of cyclohexyltriphenyltin with a cytochrome P-450 dependent monoxygenase enzyme system. Tetrahed. Lett. 40:3515-3518.

Fleet, B. and Fouzder, N.B. 1975. Electrochemical behaviour of organotin compounds. Part I. Application to the determination of trialkyl- and triaryltin derivatives. J. Electroanal. Chem. 63:59-68.

Frietag, K.-D. and Bock R. 1974a. Analysis of mixtures containing tri-, di- and monophenyltin compounds and inorganic tin (IV). Z. Anal. Chem. 270:337-346.

Freitag, K.-D. and Bock, R. 1974b. Degradation of triphenyltin chloride on sugar beet plants and in rats. Pestic. Sci. 5:731-739.

Fricke, F.L., Robbins, W.D. and Caruso, J.A. 1978. Determination of germanium, arsenic, tin, selenium and antimony by plasma emission spectrometry with hydride generation and chromatographic separation. J. Assoc. Off. Anal. Chem. 61:1118-1123.

Fuhr, A.K., Lawrence, A.W., Tong, S.S.C., Grandolfo, M.C., Hofstader, R.A., Bache, C.A., Gutenman, W.H. and Lisk, D.J. 1976. Multielement and chlorinated hydrocarbon analysis of municipal sewage sludges of American cities. Environ. Sci Technol. 10:683-687.

Gauer, W.O., Seiber, J.N. and Crosby, D.G. 1974. Determination of organotin residues from Plictran in fruit crops by gas-liquid chromatography. J. Agric. Food Chem. 22:252-254.

George, G.M., Albrecht, M.A., Frahm, L.J. and McDonnell, J.P. 1973. Atomic absorption spectrophotometric determination of dibutyltin dilaurate in finished feeds. J. Assoc. Off. Anal. Chem. 56:1480-1482.

Getzendaner, M.E. and Corbin, H.B. 1972. Residues on apples and pears from use of Plictran miticide. J. Agric. Food Chem. 20:881-885.

Gile, J.D., Collins, J.C. and Gillett, J.W. 1982. Fate and impact of wood preservatives in a terrestrial microcosm. J. Agric. Food Chem. 30:295-301.

Glockling, F. 1980. Organometallic compounds in relation to pollution. Anal. Proc. 17:417-422.

Glodowski, S. and Kublik, Z. 1980. Cyclic and stripping voltammetry of tin at mercury hanging drop and film electrodes in acidic o-diphenol media in the presence of lead and cadmium. Anal. Chim. Acta 115:51-60.

Goldberg, E.D., Hodge, V.F., Griffin, J.J., Koide, M. and Edgington, D.N. 1981. Impact of fossil fuel combustion on the sediments of Lake Michigan. Environ. Sci Technol. 15:466-471.

Guard, H.E., Cobet, A.B. and Coleman, W.M., III. 1981. Methylation of trimethyltin compounds by estuarine sediments. Science 213:770-771.

Hallas, L.E. and Cooney, J.J. 1981. Tin and tin-resistant microorganisms in Chesapeake Bay. Appl. Environ. Microbiol. 41:466-471.

Hallas, L.E. Means, J.C. and Cooney, J.J. 1982. Methylation of tin by estuarine microorganisms. Science 215:1505-1507.

Hamaguchi, H., Kuroda, R., Onuma, N., Kawabuchi, K., Mitsubayashi, T. and Hosohara, K. 1964. The geochemistry of tin. Geochim. Geophys. Acta 28:1039-1053.

Hasebe, K., Yamamoto, Y. and Kambara, T. 1982. Differential pulse-polarographic determination of organotin compounds coated on fishing nets. Fresenius Z. Anal. Chem. 310:234-238.

Hausler, D.W. and Taylor, L.T. 1981a. Nonaqueous on-line simultaneous determination of metals by size exclusion chromatography with inductively coupled plasma atomic emission spectrometric detection. Anal. Chem. 53:1223-1227.

Hausler, D.W. and Taylor, L.T. 1981b. Size exclusion chromatography of organically bound metals and coal-derived materials with inductively coupled plasma atomic emission spectrometric detection. Anal. Chem. 53:1227-1231.

Hodge, V.F., Seidel, S.L. and Goldberg, E.D. 1979. Determination of tin (IV) and organotin compounds in natural waters, coastal sediments and macro algae by atomic absorption spectrometry. Anal. Chem. 51:1256-1259.

Horwitz, W. 1979. Commonly used methods of analysis for tin in foods. J. Assoc. Off. Anal. Chem. 62:1251-1264.

Houk, C.C. and Beaulieu, H.J. 1981. Sampling and breakthrough studies with Plictran. In "Chemical Hazards in the Workplace - Measurement and Control", G. Choudhary, ed., American Chemical Society Symposium Series 149, Washington, D.C., pp. 109-121.

Huey, C., Brinckman, F.E., Grim, S. and Iverson, W.P. 1974. The role of tin in bacterial methylation of mercury. In "Proceedings of the International Conference on Transport of Persistent Chemicals in Aquatic Ecosystems", Ottawa, Ontario, May 1-3, 1974. A.S.W. deFreitas, D.J. Kushner and S.U. Qadri, eds. Published by National Research Council of Canada, pp. II-73 - II-78.

Imura, H. and Suzuki, N. 1981a. Substoichiometric isotope dilution analysis for tin with salicylideneamino-2-thiophenol complexation in non-aqueous medium. Application to the analysis of coal fly-ash. Talanta 28:73-79.

Imura, H. and Suzuki, N. 1981b. Substoichiometric determination of inorganic tin in organotin compounds. Anal. Chim. Acta 126:199-205.

Imura, H. and Suzuki, N. 1983. Fractional separation of organic and inorganic tin compounds and determination by substoichiometric isotope dilution analysis. Anal. Chem. 55:1107-1111.

Ingham, R.K., Rosenberg, S.D. and Gilman, H. 1960. Organotin compounds. Chem. Rev. 60:459-539.

Ishii, T. 1982. Tin in marine algae. Bull. Jap. Soc. Scient. Fisher. 48:1609-1615.

Iverson, W.P. and Brinckman, F.E. 1978. Microbial metabolism of heavy metals. In "Water Pollution Microbiology", Vol. 2, R. Mitchell, (ed.), J. Wiley and Sons, N.Y., pp. 201-232.

Iwai, H., Wada, O., Arakawa, Y. and Ono, T. 1982. Intestinal uptake site, enterohepatic circulation and excretion of tetra- and trialkyltin compounds in mammals. J. Toxicol. Environ. Health 9:41-49.

Jackson, J.A., Blair, W.R., Brinckman, F.E. and Iverson, W.P. 1982. Gas-chromatographic speciation of methylstannanes in the Chesapeake Bay using purge and trap sampling with a tin-selective detector. Environ. Sci. Technol. 16:110-119.

Jeltes, J. 1969. Determination of bis(tributyltin) oxide in air by atomic absorption spectroscopy or pyrolysis gas chromatography. Ann. Occup. Hyg. 12:203-207.

Jessen, E.B., Taugbol, K. and Greibrokk, T. 1979. Separation and purification of organotin halides. J. Chromatogr. 168:139-142.

Jewett, K.L. and Brinckman, F.E. 1981. Speciation of trace di- and triorganotins in water by ion-exchange HPLC-GFAA. J. Chromatogr. Sci. 19:583-593.

Jitsu, Y., Kudo, N. and Teshima, T. 1969. Determination of organotin compounds by gas-liquid chromatography. Japan Analyst 18:169-175.

Kapila, S. and Vogt, C.R. 1980. Some aspects of organic tin analysis by gas chromatography - flame photometry. J. Chromatogr. Sci. 18:144-147.

Kenis, P. and Zirino, A. 1983. Quantitative measurement of tributyltin oxide in sea water by differential pulse anodic stripping voltammetry. Anal. Chim. Acta 149:157-166

Kimmel, E.C., Fish, R.H. and Casida, J.E. 1977. Bioorganotin chemistry. Metabolism of organotin compounds in microsomal monooxygenase systems and in mammals. J. Agric. Food Chem. 25:1-9.

Kimmel, E.C., Casida, J.E. and Fish, R.H. 1980. Bioorganotin chemistry. Microsomal monoxygenase and mammalian metabolism of cyclohexyltin compounds including the miticide cyhexatin. J. Agric. Food Chem. 28:117-122.

Kojima, S. 1979. Separation of organotin compounds by using the difference in partition behaviour between hexane and methanolic buffer solution. Part I. Determination of butyltin compounds in textiles by graphite furnace atomic absorption spectrophotometry. Analyst 104:660-667.

Kolthoff, I.M. and Sandell, E.B. 1952. Textbook of Quantitative Inorganic Analysis. Third ed., MacMillan Co., N.Y., p. 604.

Komora, F. and Popl, M. 1978. The resistance of bis-tributyltin oxide to oxidation and elevated temperatures. Holztechnologie 19:145-147.

Kuwahara, R., Suzuki, T. and Meguro, H. 1980. Determination of a fungicide, triphenyltin chloride, in soil by the direct-insertion selected ion monitoring method. Agric. Biol. Chem. 44:669-670.

Leeuwangh, P., Nijman, W., Visser, H., Kolar, Z. and DeGoey, J.J.M. 1976. Toxicity of triphenyltin fungicides in the aquatic environment. Med. Fac. Landbouww. Rijksuniv. Gent 41:1483-1490.

Litan, R., Basters, J., Martijn, A., Van der Molen, T., Pasma, P., Rabenort, B. and Smink, J. 1978. Potentiometric method for determining triphenyltin compounds in formulations: collaborative study. J. Assoc. Off. Anal. Chem. 61:1504-1506.

Luke, C.L. 1956. Photometric determination of tin with phenylfluorone. Determination of tin in lead and 1% antimony-lead alloys. Anal. Chem. 28:1276-1279.

Macchi, G. and Pettine, M. 1980. Voltammetric characterization and chemical behaviour of inorganic tin in natural waters. Environ. Sci. Technol. 14:815-818.

MacCrehan, W.A. 1981. Differential pulse detection in liquid chromatography and its application to the measurement of organometal cations. Anal. Chem. 53:74-77.

Maguire, R.J. 1984. Butyltin compounds and inorganic tin in sediments in Ontario. Environ. Sci. Technol., in press.

Maguire, R.J., Carey, J.H. and Hale, E.J. 1983a. Degradation of the tri-n-butyltin species in water. J. Agric. Food Chem. 31:1060-1065.

Maguire, R.J., Chau, Y.K., Bengert, G.A., Hale, E.J., Wong, P.T.S. and Kramar, O. 1982. Occurrence of organotin compounds in Ontario lakes and rivers. Environ. Sci. Technol. 16:698-702.

Maguire, R.J. and Huneault, H. 1981. Determination of butyltin species in water by gas chromatography with flame photometric detection. J. Chromatogr. 209:458-462.

Maguire, R.J. and Tkacz, R.J. 1983. Analysis of butyltin compounds by gas chromatography: comparison of flame photometric and atomic absorption spectrophotometric detectors. J. Chromatogr. 268:99-101.

Maguire, R.J., Wong, P.T.S. and Rhamey, J.S. 1983b. Personal communication.

Maher, W. 1982. Measurement of total tin in marine organisms by stannane generation and atomic absorption spectrometry. Anal. Chim. Acta 138:365-370.

Makarenko, N.P. and Yashin, Y.I. 1983. Analysis of organometallic compounds by liquid chromatography. J. Chromatogr. 257:59-67.

Marr, I.L. and Anwar, J. 1982. Micro-determination of tin in organotin compounds by flame emission and atomic absorption spectrophotometry. Analyst 107:260-268.

Mazayev, V.T., Golovanov, O.V., Igumnov, A.S. and Tsai, V.N. 1976. On the transformation of organotin compounds in an aqueous medium. Gigiena i sanitaria No. 3:17-20.

McGuffin, V.L. and Novotny, M. 1981a. Microcolumn high-performance liquid chromatogrpahy and flame-based detection principles. J. Chromatogr. 218:179-187.

McGuffin, V.L. and Novotny, M. 1981b. Flame emission detection in microcolumn liquid chromatography. Anal. Chem. 53:946-951.

Meinema, H.A., Burger-Wiersma, T., Versluis-de Hann, G. and Gevers, E.Ch. 1978. Determination of trace amounts of butyltin compounds in aqueous systems by gas chromatography/mass spectrometry. Environ. Sci. Technol. 12:288-293.

More, E., Beccaria, A.M. and Poggi, G. 1973. Determinazione di piccole quantita' di stagno in composti organometallici disciolti in acqua marina. Annali di Chim. 63:173-180.

Negishi, E.-I. 1980. Organometallics in organic synthesis. Vol. I. Organometallics of main group metals in organic synthesis. Wilev Interscience, N.Y., pp. 394-454.

Neubert, G. and Wirth, H.O. 1975. The analysis of organotin stabilizers. Zeitschrift fur Analytische Chemie 276:19-23.

Neumann, W.P. 1970. The organic chemistry of tin. Interscience Publishers (J. Wiley, N.Y.), 282 pp.

Ohta, K. and Suzuki, M. 1979. Atomic absorption spectrometry of tin with electrothermal atomization in a molybdenum microtube. Anal. Chim. Acta 107:245-251.

Parks, E.J., Brinckman, F.E. and Blair, W.R. 1979. Application of a graphite furnace atomic absorption detector automatically coupled to a high-performance liquid chromatograph for speciation of metal-containing macromolecules. J. Chromatogr. 185:563-572.

Parks, E.J., Johannesen, R.B. and Brinckman, F.E. 1983. Characterization of organometallic copolymers and copolymerization by size-exclusion chromatography coupled with trace metal- and mass-sensitive detectors. J. Chromatogr. 255:439-454.

Parris, G.E., Blair, W.R. and Brinckman, F.E. 1977. Chemical and physical considerations in the use of atomic absorption detectors coupled with a gas chromatograph for determination of trace organometallic gases. Anal. Chem. 49:378-388.

Peterson, P.J., Burton, M.A.S., Gregson, M., Nye, S.M. and Porter, E.K. 1976. Tin in plants and surface waters in Malaysian ecosystems. Trace Subs. Environ. Health 10: 123-132.

Piscator, M. 1979. Tin. In "Handbook on the Toxicology of Metals", L. Friberg, G.F. Nordberg and V.B. Vouk, eds., Elsevier - North Holland Biomedical Press, Amsterdam, pp. 613-626.

Pollard, F.H., Nickless, G. and Coke, D.J. 1964. Chromatographic studies on organotin compounds. Part I. The gas chromatography of alkyltin compounds. J. Chromatogr. 13:48-55.

Poller, R.C. 1970. The chemistry of organotin compounds. Academic Press, N.Y., 315 pp.

Putnam, R.C. and Pu, H. 1965a. Retention indices of organotins. J. Gas Chromatogr. 3:160-164.

Putnam, R.C. and Pu, H. 1965b. Retention times of organotins (II). J. Gas Chromatogr. 3:289-293.

Pyen, G. and Fishman, M. 1979. Automated determination of tin in water. Atom. Absorpt. Newslett. 18:34-36.

Rayson, G.D. and Holcombe, J.A. 1982. Tin atom formation in a graphite furnace atomizer. Anal. Chim. Acta 136:249-260.

Ritchie, L.S. and Berrios-Duran, L.A. 1969. Chemical stability of molluscicidal compounds in water. Bull. W.H.O. 40:471-473.

Robbins, W.B., Caruso, J.A. and Fricke, F.L. 1979. Determination of germanium, arsenic, selenium, tin and antimony in complex samples by hydride generation-microwave-induced plasma atomic emission spectrometry. Analyst 104:36-40.

Ross, W.J. and White, J.C. 1961a. Application of pyrocatechol violet as a colorimetric reagent for tin. Anal. Chem. 33:421-424 (1961).

Ross, W.J. and White, J.C. 1961b. Extraction of tin with tris (2-ethylhexyl) phosphine oxide and its determination in nonaqueous medium with pyrocatechol violet. Anal. Chem. 33:424-427.

Sano, M., Furukawa, M., Kourai, M. and Tomita, I. 1979. Flameless atomic absorption spectrophotometric determination of Vendex, an organic tin miticide, in apples, oranges and tea leaves. J. Assoc. Off. Anal. Chem. 62:764-768.

Sawyer, A.K. 1971. Editor of "Organotin Compounds", Vol. 1, 2 and 3. Marcel Dekker, N.Y., 1077 pp.

Schatzberg, P. and Harris, L. 1978. Organotin detoxification. In "Report of the Organotin Workshop", M. Good, ed., Univ. of New Orleans, New Orleans, LA, Feb. 17-19, pp. 95-107.

Schmidt, F.J., Royer, J.L. and Muir, S.M. 1975. Automated determination of arsenic, selenium, antimony, bismuth and tin by atomic absorption utilizing sodium borohydride reduction. Anal. Lett. 8:123-128.

Schramel, P., Samsahl, K. and Pavlu, J. 1973. Some determinations of Hg, As, Se, Sb, Sn and Br in water plants, sediments and fishes in Bavarian rivers. Intern. J. Environ. Stud. 5:37-40.

Seidel, S.L. Hodge, V.F. and Goldberg, E.D. 1980. Tin as an environmental pollutant. Thalassia Jugoslavica 16:209-222.

Sheldon, A.W. 1975. Effects of organotin antifouling coating on man and his environment. J. Paint Technol. 47:54-58.

Sheldon, A.W. 1978. Dissipation and detoxification of organotins in the environment. Proc. Ann. Mar. Coat. Conf. 18:IX-1 to IX-18.

Sherman, L.R. and Carlson, T.L. 1980. A modified phenylfluorone method for determining organotin compounds in the ppb and sub-ppb range. J. Anal. Toxicol. 4:31-33.

Skeel, R.T. and Bricker, C.E. 1961. Spectrophotometric determination of dibutyltin dichloride. Anal. Chem. 33:428-431.

Sleesinger, A.E. and Dressler, I. 1978. The environmental chemistry of three organotin chemicals. In "Report of the Organotin Workshop", M. Good, ed., Univ. of New Orleans, New Orleans, LA, Feb. 17-19, pp. 115-162.

Smith, G.N., Fischer, F.S. and Axelson, R.J. 1976. Volatilization and photodecomposition of Plictran miticide. J. Agric. Food Chem. 24:1225-1229.

Smith, J.D. 1970. Tin in organisms and water in the Gulf of Naples. Nature 225:103-104.

Smith, J.D. and Burton, J.D. 1972. The occurrence and distribution of tin with particular reference to marine environments. Geochim. Cosmochim. Acta 36:621-629.

Smith, P.J., Crowe, A.J., Allen, D.W., Brooks, J.S. and Formstone, R. 1977. A study by 119 m-Sn Mossbauer spectroscopy of bis(tri-n-butyltin) oxide adsorbed on cellulosic materials. Chem. Ind., pp. 874-875.

Soderquist, C.J. and Crosby, D.G. 1978. Determination of triphenyltin hydroxide and its degradation products in water. Anal. Chem. 50:1435-1439.

Soderquist, C.J. and Crosby, D.G. 1980. Degradation of triphenyltin hydroxide in water. 1980. J. Agric. Food Chem. 28:111-117.

Steinmeyer, R.D., Fentiman, A.F. and Kahler, E.J. 1965. Analysis of alkyltin bromides by gas liquid chromatography. Anal. Chem. 37:520-523.

Stewart, T.E. and Cannizzaro, R.D. 1980. Analysis of organotin pesticide residues by gas chromatography-mass spectrometry. In "Pesticide Analytical Methodology", J. Harvey Jr., G. Zweig, R. Cannizzaro, H. Dishburger and J. Sherma, eds., American Chemical Society Symposium Series 136, Washington, D.C., pp. 367-388.

Stroganov, N.S., Parina, O.V. and Sorvachev, K.F. 1973. Uptake of triethyltin chloride from the water and its distribution in the organs and tissue of the carp. Hydrobiol. J. 9:45-52.

Tam, G.K.H., Lacroix, G. and Lawrence, J.F. 1983. Gas chromatographic separation of mono-, di- and trimethyltin chlorides and tetramethyltin. J. Chromatogr. 259:350-352.

Thompson, K.C., Godden, R.G. and Thomerson, D.R. 1975. A method for the formation of pyrolytic graphite coatings and enhancement by calcium addition techniques for graphite rod flameless atomic absorption spectrometry. Anal. Chim. Acta 74:289-297.

Tobias, R.S. 1966. Sigma-bonded organometallic cations in aqueous solutions and crystals. Organometal. Chem. Rev. 1:93-129.

Trachman, H.L., Tyberg, A.J. and Branigan, P.D. 1977. Atomic absorption spectrometric determination of sub-part-per-million quantities of tin in extracts and biological materials with a graphite furnace. Anal. Chem. 49:1090-1093 (1977).

Tugrul, S., Balkas, T.I. and Goldberg, E.D. 1983. Methyltins in the marine environment. Mar. Pollut. Bull. 14:297-303.

Udris, J. 1971. The analysis of tin stabilizers used in poly (vinyl chloride) compositions. Analyst 96:130-139.

Varnes, A.W. and Gaylor, V.F. 1978. Determination of dioctyltin stabilizers in food-simulating solvents by atomic absorption spectrometry with electrothermal atomization. Anal. Chim. Acta 101:393-399.

Vernon, F. 1974. The fluorimetric determinaion of triphenyltin compounds. Anal. Chim. Acta 71:192-195.

Vickrey, T.M., Harrison, G.V. and Ramelow, G.J. 1981. Treated graphite surfaces for determination of tin by graphite furnace atomic absorption spectrometry. Anal. Chem. 53:1573-1576.

Vickrey, T.M., Harrison, G.V., Ramelow, G.J. and Carver, J.C. 1980b. Use of metal carbide coated graphite cuvettes for the atomic absorption analysis of organotins. Anal. Lett. 13:781-795.

Vickrey, T.M., Howell, H.E., Harrison, G.V. and Ramelow, G.J. 1980a. Post column digestion methods for liquid chromatography - graphite furnace atomic absorption speciation of organolead and organotin compounds. Anal. Chem. 52:1743-1746.

Vigan, P.N. and Chan, C.Y. 1976. Determination of tin by gas phase atomization and atomic absorption spectrometry. Anal. Chem. 48:1788-1792.

Ward, G.S., Cramm, G.C., Parrish, P.R., Trachman, H. and Slesinger, A. 1981. Bioaccumulation and chronic toxicity of bis(tributyltin) oxide (TBTO): tests with a salt water fish. In, "Aquatic Toxicology and Hazard Assessment: Fourth Conference. ASTM STP 737", D.R. Branson and K.L. Dickson, eds., American Society for Testing and Materials, pp. 183-200.

Wiebkin, P., Prough, R.A. and Bridges, J.W. 1982. The metabolism and toxicity of some organotin compounds in isolated rat hepatocytes. Toxicol. Appl. Pharmacol. 62:409-420.

Winge, R.K., Katzenberger, J.M. and Kniseley, R.N. 1977. Evaluation of an inductively-coupled plasma multichannel spectrometric analysis system. Environmental Monitoring Series report EPA-600/4-77-032 (June 1977), Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA. 30601, 46 pp.

Woggon, H. and Jehle, D. 1975. The residue analysis of biocidal organotin compounds using anodic stripping voltammetry. Die Nahrung 19:271-275.

Woggon, H., Sauberlich, H. and Uhok, W.-J. 1972. A contribution to the determination (anodic stripping method) of organotin compounds and their degradation and decomposition products. Z. Anal. Chem. 260:268-274.

World Health Organization Task Group on Environmental Health Aspects of Tin and Organotin Compounds. 1980. Tin and organotin compounds: a preliminary review. Environmental Health Criteria Series No. 15, World Health Organization, Geneva, Switzerland, 109 pp.

Wright, B.W., Lee, M.L. and Booth, G.M. 1979. Determination of triphenyltin hydroxide derivatives by capillary gc and tin-selective fpd. J. High Resol. Chromatogr. Chromatogr. Commun. 2:189-190.

Yu, T.-H. and Arakawa, Y. 1983. High-performance liquid chromatographic determination of dialkyltin homologues using fluorescence detection. J. Chromatogr. 258:189-197.

Yamada, J., Tatsuguchi, K. and Watanabe, T. 1978. Uptake of tripropyltin chloride by Escherichia coli. Agric. Biol. Chem. 42:1867-1870.

Zuckerman, J.J. 1976. Editor of "Organotin Compounds: New Chemistry and Applications", Advances in Chemistry Series 157, American Chemical Society, Washington, D.C., 299 pp.

Zuckerman, J.J. Reisdorf, R.P., Ellis, H.V., III and Wilkinson, R.R. 1981. Organotins in biology and the environment. In "Organometals and Organometalloids, Occurrence and Fate in the Environment", F.E. Brinckman and J.M. Bellama, eds., American Chemical Society, Washington, D.C. American Chemical Society Symp. Ser. No. 82, pp. 388-422.

TABLE 1: Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
1	Sn^{2+}	water	iodometric titration in absence of air			Kolthoff and Sandell (1952)
2	Sn^{2+}	water	asv	125 µg/L	Sn^{2+} in a chloride solution in MeOH is only 1% converted to Sn^{4+} in 10 hr	Fano and Zanotti (1973)
3	Sn^{2+}	water	carbon filament aas	100 pg	linear range up to 8 ng; 224.6 nm	Everett et al. (1974)
4	Sn^{2+}	water	carbon filament aas	70 pg	286.3 nm, with edl; linear range up to 10 ng	Everett et al. (1974)
5	Sn^{2+}	xylene	carbon filament aas	150 pg	286.3 nm; linear range up to 20 ng	Everett et al. (1974)
6	Sn^{2+}	SAE 10 oil	carbon filament aas	180 pg	286.3 nm; linear range up to 6 ng	Everett et al. (1974)
7	Sn^{2+}	water	hydride derivatization; SnH_4 detected by gc-fpd	36 ng/L	this reaction interferes with the hydride derivatization method for Sn^{4+}	Brinckman et al. (1983)
8	Sn^{4+}	in lead and in 1% antimony-lead alloys	spectrophotometric determination of phenylfluorone complex	microgram quantities		Luke (1956)
9	Sn^{4+}	water	fluorescence determination of flavonol complex	0.1 µg/mL	33% dimethylformamide preferred for solvent	Coyle and White (1957)
10	Sn^{4+}	water	spectrophotometric determination of phenylfluorone complex	20 µg/L	a modification of method No. 8	Bennett and Smith (1959)
11	Sn^{4+}	water	spectrophotometric determination of pyrocatechol violet complex	240 µg/L	Zr, Ti, Bi, Sb, Ga and Mb interfere, but Sn^{2+} does not	Ross and White (1961a)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
12	Sn^{4+}	EtOH	extracted from acidic solution with tris (2-ethylhexyl) phosphine oxide, diluted with EtOH, followed by method No. 11	10 µg/L	method used in Pb, Zn, Cu, Fe and Zr-based alloys	Ross and White (1961b)
13	Sn^{4+}	sea water, rocks, clays, marine animals	acid digestion (if necessary), conversion to SnO_2 and naa		exhaustive purification steps required	Hamaguchi et al. (1964)
14	Sn^{4+}	ethereal solution of $SnBr_4$	Grignard conversion to Me_4Sn, then gc-tcd			Steinmayer et al. (1965)
15	Sn^{4+}	standards	Grignard conversion to Pr_4Sn or Pe_4Sn, then gc-tcd			Jitsu et al. (1969)
16	Sn^{4+}	acidic aqueous	(a) distillation of $SnBr_4$ with HBr-HCl mixture, or (b) extraction of $SnBr_4$ into hexane, then spectrophotometric determination of dithiol complex	0.2 mg Sn		Corbin (1970)
17	Sn^{4+}	acidic solution, either of sea water or tissue digests	extraction of SnI_4 into dilute NaOH, then spectrophotometric determination of phenyl-fluorone complex	0.1 µg Sn		Smith (1970)
18	Sn^{4+}	water	asv	40 µg/L		Noggon et al. (1972)

Cont'd...../

TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
19	Sn^{4+}	acidic aqueous solution	see method No. 11	1µg	cetyltrimethylammonium bromide sensitizes the reaction	Corbin (1973)
20	Sn^{4+}	acidic solution (steel digest)	see method No. 11		sensitization with surfactants and basic dyes; metal interferences were shown, as well as ways to remove the interferences	Ashton et al. (1973)
21	Sn^{4+}	fresh water or freeze-dried plants, sediment and fish	naa			Schramel et al. (1973)
22	Sn^{4+}	water (pH4)	extraction with diethyl-dithiocarbanate in $CHCl_3$, then spectrophotometric determinations of dithiol complex			Freitag and Bock (1974a)
23	Sn^{4+}	on sugar beet plants and in rats	radioactive ^{113}Sn determination after extraction as per method No. 22			Freitag and Bock (1974b)
24	Sn^{4+}	water	generation of SnH_4, then aas with Ar/H_2 flame	1ng		Schmidt et al. (1975)
25	Sn^{4+}	water	gfaas		response increased by (a) addition of Ca^{2+}, and (b) addition of propane, ethylene, acetylene or methane to purge gas, which results in deposition of pyrolytic graphite; the two effects are not additive	Thompson et al. (1975)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
26	Sn^{4+}	suspended particulate matter in air	Sn dissolved from Hi-Vol filter, then SnH_4 generation and aas with a quartz tube furnace	0.1 µg/L	response linear to 40 µg/L; λ=286.3 mm (sensitivly 66% higher at 224.6 mm, but considerable baseline drift); analyses also done on beverages	Vijan and Chan (1976)
27	Sn^{4+}	municipal sewage sludges	naa			Fuhr et al. (1976)
28	Sn^{4+}	tlc plates	$^{119}Sn^{4+}$ located with dithizone, then analyzed in scintillation counter			Smith et al. (1976)
29	Sn^{4+}	water	icp-aes	50-120 µg/L		Winge et al. (1977)
30	Sn^{4+}	tlc plates	chromogenic reagents: either pyrocatechol violet or 8-hydroxy-5-quinolinesulfonic acid	1-10 µg/spot		Kimmel et al. (1977)
31	Sn^{4+}	water	SnH_4 generation, then plasma aes	40 ng	linear range 0.1-10 µg; hydride generator coupled to spectrometer via a condensation tube and Chromosorb 102 column to separate SnH_4 from H_2	Fricke et al. (1978)
32	Sn^{4+}	water	extraction with 0.05% tropolone in C_6H_6 or $CHCl_3$, Grignard derivatization to Bu_4Sn, then gc-ms		80-90% recovery at 1 mg/L level; strong tendency noted for Sn to adsorb to glass	Meinema et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
33	Sn^{4+}	water, sediment suspended solids	after digestion (if necessary), SnH_4 generation, then aas with quartz tube furnace	1 µg/L or 0.1 µg/g	a refinement of method No. 26	Pyen and Fishman (1979)
34	Sn^{4+}	fresh, estuarine, sea, tap and rain water, and urine	SnH_4 generation, then flame emission detection (610 nm)	0.3 ng/L for 100 mL samples	H_2-rich flame; $NaBH_4$ reagent frequently contaminated with Sn	Braman and Tompkins (1979)
35	Sn^{4+}	shells (miscellaneous)	SnH_4 generation, then flame emission detection (610 nm)	0.05 ng/g	method of digestion of (or extraction from) shells not stated	Braman and Tompkins (1979)
36	Sn^{4+}	fresh and sea water, marine algae, sediment	SnH_4 generation from digests (if necessary), then aas with quartz tube furnace	0.4 ng		Hodge et al. (1979)
37	Sn^{4+}	juices	aas with Mo micro-tube furnace	9 pg	addition of H_2 to Ar purge gas improves efficiency of Sn atomization; phosphoric acid lowers atomization temperature and depresses some interferences	Ohta and Suzuki (1979)
38	Sn^{4+}	food	digestion, SnH_4 generation, then aas with quartz tube furnace	0.2 mg/kg	good statistical evaluation of results; furnace heated only by flame	Evans et al. (1979)
39	Sn^{4+}	flour and whole blood	digestion, SnH_4 generation, then microwave-induced Ar-He plasma aes	2 µg/L for 20 mL aqueous standard		Robbins et al. (1979)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
40	Sn^{4+}	pure and tap water	asv	1 µg/L	can be determined in the presence of five-fold excess of Pb^{2+} and Cd^{2+}; effects of diphenols and oxalic acid demonstrated	Glodowski and Kublik (1980)
41	Sn^{4+}	artificial sea water	dpasv	8 µg/L		Macchi and Pettine (1980)
42	Sn^{4+}	rocks, in presence of other metals and metalloids	MIBK extraction, then selective back-extraction and flame aas			Clark and Viets (1980)
43	Sn^{4+}	dialkylbenzene sulfonate salt in toluene	size exclusion chromatography with icp-aes	41 µg/L	100-Angstrom µ-Styragel column	Hausler and Taylor (1981a)
44	Sn^{4+}	"petroleum-based organic matrix"	size exclusion chromatography with icp-aes	220 µg/L	pyridine solvent	Hausler and Taylor (1981b)
45	Sn^{4+}	coal fly ash	digestion, substoichiometric isotope dilution analysis by complexation in benzene with salicylideneamino-2-thiophenol	1 µg		Imura and Suzuki (1981a)
46	Sn^{4+}	as contaminant in organotin compounds	extraction with iodide, then method No. 45		butyltin compounds in 5×10^3-fold excess amounts do not interfere	Imura and Suzuki (1981b)
47	Sn^{4+}	aqueous standards	gfaas		Zr-coated furnaces increased atomization efficiency by 2-3 X	Vickrey et al. (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
48	Sn^{4+}	pure and fresh water	extraction with tropolone in C_6H_6, Grignard derivatization to Pe_4Sn, then gc-modified-fpd	60 pg	> 94% recovery at 10 ng/L level	Maguire and Huneault (1981)
49	Sn^{4+}	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 36	0.5 ng	linear range over 0.05-1 µg/L for 100 mL sample	Boettner et al. (1981)
50	Sn^{4+}	"artificial tap water" extracts of new PVC and CPVC pipe	extraction with tropolone in C_6H_6, Grignard derivatization to Pe_4Sn, then gc-fid	1.5-3 µg/L (1 L sample)		Boettner et al. (1981)
51	Sn^{4+}	water and sediment	(a) sediment leached with acid; (b) water extracted with MIBK after addition of ammonium pyrolidine dithiocarbonate; gfaas			Hallas and Cooney (1981)
52	Sn^{4+}	pure and fresh water	saturation with NaCl, extraction with tropdone in C_6H_6, Grignard derivatization to $n\text{-}Bu_4Sn$, then gc-aas with quartz tube furnace	100 pg Sn		Chau et al. (1982)
53	Sn^{4+}	aqueous standard	gfaas		addition of 10% H_2 to purge gas increases sensitivity	Reyson and Holcombe (1982)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
54	Sn^{4+}	estuarine water	SnH_4 generation to purge and trap sampler, then gc-modified-fpd	0.03 µg/L with 10 mL samples		Jackson et al, (1982)
55	Sn^{4+}	sea water, marine algae, sediment	SnH_4 generation from digests (if necessary), then aas with quartz tube furnace	5 ng/L in sea water		Ishii (1982)
56	Sn^{4+}	with $BuSn^{3+}$, Bu_2Sn^{2+} and Bu_3Sn^{+} in benzene	separation of species with selective halide extraction, then analysis by method No. 44			Imura and Suzuki (1983)
57	Sn^{4+}	sediment	dry sediment extracted with tropolone in C_6H_6, then analysis by method No. 48	5 µg/kg with 1 g samples	this work also dealt with Bu_3MeSn and Bu_2Me_2Sn in sediment	Maguire (1984)
58	Sn^{4+}	water	extraction according to method No. 48, with analysis either by gc-modified-fpd or gc-aas with quartz tube furnace	~60 pg	sensitivity of the two detectors roughly the same, but quartz furnace more stable	Maguire and Tkacz (1983)
59	Sn^{4+}	water	SnH_4 generation then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	to avoid adsorption of hydride to internal surfaces of detection apparatus, all inner surfaces deactivated with silylating agent	Andreae (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
60	$SnCl_4$	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		discontinuous method since only part of effluent is sampled, giving nomographic presentation of results; Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980a)
61	$SnCl_4$	MeOH	gfaas	13-19 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
62	SnO_2	precipitated from water during degradation of Ph_3Sn^+	fusion with $KHSO_4$ at 300-350°; solubilized Sn^{4+} then analyzed by method No. 19			Soderquist and Crosby (1978)
63	"total Sn"	solvent extracts from PVC films	gfaas	0.1 ng	linear range to 0.75 ng; no species-dependent sensitivity even without Zr-coating of furnace	Trachman et al. (1977)
64	"total Sn"	beef tissues	digestion with a quarternary ammonium hydroxide dissolved in toluene, then gfaas	0.1 ng	apparently no lipid interferences	Trachman et al. (1977)
65	"total Sn"	water	preconcentration by coprecipitation with 1,10-phenanthroline and Ph_4B, then gfaas	0.1 ng	linear range 0.4-14 ng	Dogan and Haerdi (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
66	"total Sn"	plants, plankton, fish organic component of sediment	digestion with quaternary ammonium hydroxide in 1-propanol, then gfaas	0.1 ng	apparently no lipid interferences	Dogan and Haerdi (1980)
67	"total Sn"	water	extracted with hexane, oxidized with H_2SO_4, then spectrophotometric determination of phenylfluorone complex		yield not stated	Sherman and Carlson (1980)
68	"total Sn"	soil	extracted with hexane, oxidized with H_2SO_4, then spectrophotometric determination of phenylfluorone complex		yield not stated	Sherman and Carlson (1980)
69	"total Sn"	plants, fish	dissolved in H_2SO_4, then method No. 67		yield not stated	Sherman and Carlson (1980)
70	"total Sn"	marine algae, fish, molluscs	acid digestion, SnH_4 generation, then aas with silica tube furnace	0.9 µg/L of analyte		Maher (1982)
71	$MeSn^{3+}$	$MeSnCl_3$ in Et_2O	Grignard derivatization to $MeBu_3Sn$ or $MeOct_3Sn$, then gc with tcd or hot wire detector			Neubert and Wirth (1975)
72	$MeSn^{3+}$	water	270 MHz nuclear magnetic resonance			Dizikes et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
73	$MeSn^{3+}$	fresh, estuarine, sea, tap and rain water, and urine	$MeSnH_3$ generation and detection by method No. 34	0.01-0.02 ng/L for 100 mL samples		Braman and Tompkins (1979)
74	$MeSn^{3+}$	shells (miscellaneous)	$MeSnH_3$ generation and detection by method No. 34	0.01 ng/g	method of extraction from shells not stated	Braman and Tompkins (1979)
75	$MeSn^{3+}$	fresh and sea water	$MeSnH_3$ generation, then method No. 36	0.5 ng		Hodge et al. (1979)
76	$MeSn^{3+}$	$MeSnCl_3$ in organic solvents	hplc-rid		various column packing materials tested	Jessen et al. (1979)
77	$MeSn^{3+}$	$MeSnCl_3$ in organic solvents	(a) gc-hot wire detector, or (b) hplc-rid	(a) could not be determined in presence of Me_4Sn (b) 100 µg	(a) redistribution reaction occurs if Me_4Sn were present	Burns et al. (1980)
78	$MeSn^{3+}$	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
79	$MeSn^{3+}$	$MeSnCl_3$ standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
80	$MeSn^{3+}$	$MeSnCl_3$ standards	hplc, then $MeSnH_3$ generation, then electrothermal aas	1 ng	no detail given on detector; this method failed for mixtures of butyl or phenyl-tin halides, owing to the lower volatility of the resulting hydrides	Glockling (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
81	$MeSn^{3+}$	$MeSnCl_3$ standards	hplc-flame aas	19 ng	N_2O-C_2H_2 flame	Burns et al. (1981)
82	$MeSn^{3+}$	$MeSnCl_3$ standards	gcass with quartz tube furnace	1.1 ng	redistribution reaction occurs if Me_4Sn is present	Burns et al. (1981)
83	$MeSn^{3+}$	$MeSnCl_3$ standards	hplc, then $MeSnH_3$ generation, then aas with quartz tube furnace	5.4 pg		Burns et al. (1981)
84	$MeSn^{3+}$	"artificial-tap water" extracts of new PVC and CPVC pipe	see method No. 75	0.5 ng	linear range over 0.05-1 µg/L for mL sample	Boettner et al. (1981)
85	$MeSn^{3+}$	water	method No. 52 with $MeBu_3Sn$ species	0.04 µg/L, with 5L sample		Chau et al. (1982)
86	$MeSn^{3+}$	$MeSnH_3$	gc-ecd			Hallas et al. (1982)
87	$MeSn^{3+}$	estuarine water	method No. 54 with $MeSnH_3$ species	0.05 µ/L with 10 mL samples		Jackson et al. (1982)
88	$MeSn^{3+}$	marine algae	homogenized, and resulting supernatant analyzed by method No. 55 for $MeSnH_3$			Ishii (1982)
89	$MeSn^{3+}$	$MeSnCl_3$ standards	gc-fid	0.1 µg		Tam et al. (1983)
90	$MeSn^{3+}$	$MeSnCl_3$ in CCl_4 or water	^1H nuclear magnetic resonance spectroscopy			Blunden (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
91	$MeSn^{3+}$	water	$MeSnH_3$ generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreae (1983)
92	Me_2Sn^{2+}	atmosphere above culture media	ms			Huey et al. (1974)
93	Me_2Sn^{2+}	Me_2SnCl_2 in Et_2O	method No. 71 with Me_2Bu_2Sn or Me_2Oct_2Sn			Neubert and Wirth (1975)
94	Me_2Sn^{2+}	fresh, estuarine, sea, tap and rain water, and urine	Me_2SnH_2 generation and detection by method No. 34	0.01-0.03 µg/L for 100 mL samples		Braman and Tompkins (1979)
95	Me_2Sn^{2+}	shells (miscellaneous)	Me_2SnH_2 generation and detection by method No. 34	0.01 ng/g	method of extraction from shells not stated	Braman and Tompkins (1979)
96	Me_2Sn^{2+}	fresh and sea water	Me_2SnH_2 generation, then method No. 36	0.5 ng		Hodge et al. (1979)
97	Me_2Sn^{2+}	Me_2SnCl_2 standards	hplc-rid		various column packing materials tested	Jessen et al. (1979)
98	Me_2Sn^{2+}	Me_2SnCl_2	see method No. 77, (a) and (b)	(a) 8 µg (b) 90 µg	see method No. 77	Burns et al. (1980)
99	Me_2Sn^{2+}	Me_2SnCl_2 in MeOH	gfaas	9-22 pg	Zr-treated furnaces	Vickrey et al. (1980b)
100	Me_2Sn^{2+}	Me_2SnCl_2 standards	hplc-rid		acetone-pentane solvent	Glockling (1980)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
101	Me_2Sn^{2+}	Me_2SnCl_2 standards	hplc, then Me_2SnH_2 generation, then electo-thermal aas	1 ng	see method No. 80	Glockling (1980)
102	Me_2Sn^{2+}	water	spectrophotometric determination of 3-hydroxy-flavone complex		ϵ_{385} = 4.7×10^4 L mole^{-1} cm^{-1}	Aldridge and Street (1981)
103	Me_2Sn^{2+}	Me_2SnCl_2 standards	hplc-flame aas	17 ng	N_2O-C_2H_2 flame	Burns et al. (1981)
104	Me_2Sn^{2+}	Me_2SnCl_2 standards	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)
105	Me_2Sn^{2+}	Me_2SnCl_2 standards	hplc, then Me_2SnH_2 generation, then aas with quartz tube furnace	8.6 pg		Burns et al. (1981)
106	Me_2Sn^{2+}	Me_2SnCl_2 standards	gc, then Me_2SnH_2 generation and aas with quartz tube furnace	1.5 pg		Burns et al. (1981)
107	Me_2Sn^{2+}	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 96	0.5 ng	linear range over 0.05 to 1 µg/L for 100 mL sample	Boettner et al. (1981)
108	Me_2Sn^{2+}	water	method No. 52 with Me_2Bu_2Sn species	0.04 µg/L, 5 L sample		Chau et al. (1982)
109	Me_2Sn^{2+}	atmosphere above cultures	Me_2SnH_2 derivative analyzed by gc-ecd and gc-ms			Hallas et al. (1982)
110	Me_2Sn^{2+}	estuarine water	method No. 54 with Me_2SnH_2 species	0.01 µ/L with 10 mL samples		Jackson et al. (1982)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
111	Me_2Sn^{2+}	marine algae	method No. 88 for Me_2SnH_2 species			Ishii (1982)
112	Me_2Sn^{2+}	spiked rat tissues	homogenization, extraction with EtOAc, partitioning into hexane, then hplc with fluorescence detection of 2',3,4',5,7-pentahydroxyflavone complex	0.1 to 1 ng	91% recovery from tissues spiked at 5 mmole level	Yu and Arakawa (1983)
113	Me_2Sn^{2+}	Me_2SnCl_2 standards	gc-fid	0.1 µg		Tam et al. (1983)
114	Me_2Sn^{2+}	Me_2SnCl_2 in CCl_4 or water	^1H nuclear magnetic resonance spectroscopy			Blunden (1983)
115	Me_2Sn^{2+}	water	Me_2SnH_2 generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreae (1983)
116	Me_3Sn^+	Me_3SnCl standard	gc-fpd	10 ng	linear response to 10^4 ng	Aue and Hill (1972a)
117	Me_3Sn^+	Me_3SnCl in Et_2O	method No. 71 with Me_3BuSn or Me_3OctSn			Neubert and Wirth (1975)
118	Me_3Sn^+	fresh, estuarine, sea, tap and rain water and urine	Me_3SnH generation and detection by method No. 34	0.01 to 0.02 ng/L for 100 mL samples		Braman and Tompkins (1979)
119	Me_3Sn^+	Me_3SnCl standards	Me_3SnH generation, then method No. 36	0.4 ng		Hodge et al. (1979)
120	Me_3Sn^+	Me_3SnCl standards	hplc-rid		various column packing materials tested	Jessen et al. (1979)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
121	Me_3Sn^+	Me_3SnCl standards	see method No. 77, (a) and (b)	(a) 8 µg (b) 80 µg	see method No. 77	Burns et al. (1980)
122	Me_3Sn^+	MeOH/water (97.5/2.5,v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
123	Me_3Sn^+	Me_3SnCl standards	gfaas	26 to 51 pg	Zr-treated furnaces	Vickrey et al. (1980b)
124	Me_3Sn^+	Me_3SnCl standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
125	Me_3Sn^+	Me_3SnCl standards	hplc, then Me_3SnH generation, then electrothermal aas	1 ng	see method No. 80	Glockling (1980)
126	Me_3Sn^+	MeOH	ion exchange hplc-gfaas		possible volatilization during dry and ash cycles	Jewett and Brinckman (1981)
127	Me_3Sn^+	MeOH	hplc-dppd			MacCrehan (1981)
128	Me_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex	82 ng		Aldridge and Street (1981)
129	Me_3Sn^+	Me_3SnCl standards	hplc-flame aas	16 ng	N_2O-C_2H_2 flame	Burns et al. (1981)
130	Me_3Sn^+	Me_3SnCl standards	gc-aas with quartz tube furnace	1.2 ng		Burns et al. (1981)
131	Me_3Sn^+	Me_3SnCl standards	hplc, then Me_3SnH generation, then aas with quartz tube furnace	9.5 pg		Burns et al. (1981)
132	Me_3Sn^+	Me_3SnCl standards	gc, then Me_3SnH generation, then aas with quartz tube furnace	2 pg		Burns et al. (1981)
133	Me_3Sn^+	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 119	0.5 ng	linear range over 0.05 to 1 µg/L for 100 mL samples	Boettner et al. (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
134	Me_3Sn^+	water	method No. 52 with Me_3BuSn species	0.04 µg/L, 5 L sample		Chau et al. (1982)
135	Me_3Sn^+	atmosphere above cultures	Me_3SnH derivative analyzed by gc-ecd and gc-ms			Hallas et al. (1982)
136	Me_3Sn^+	estuarine water	method No. 54 with Me_3SnH species	~0.01 µg/L, for 10 mL samples		Jackson et al. (1982)
137	Me_3Sn^+	marine algae	method No. 88 for Me_3SnH species			Ishii (1982)
138	Me_3Sn^+	Me_3SnCl standards	gc-fid	10 ng		Tam et al. (1983)
139	Me_3Sn^+	Me_3SnCl in CCl_4 or water	^1H nuclear magnetic resonance spectroscopy			Blunden (1983)
140	Me_3Sn^+	water	Me_3SnH generation, then swept into (a) aas with quartz tube furnace, or (b) fpd	(a) 90 pg (b) 10 pg	see method No. 58	Andreae (1983)
141	Me_4Sn	standards	gc with (a) tcd, (b) fid, and (c) gas density balance detectors		relative sensitivities are (a) 1, (b) 1.7 and (c) 10	Pollard et al. (1964)
142	Me_4Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
143	Me_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
144	Me_4Sn	standards	gc-fpd	10 ng	linear response to 10^4 ng	Aue and Hill (1972a)
145	Me_4Sn	standards	gc-gfaas	12 ng Sn	transfer line maintained at 100°C; graphite furnace run continuously at 1800°C; H_2 added to Ar carrier gas	Parris et al. (1977)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
146	Me_4Sn	standards	hplc-rid		various column packing materials tested	Jessen et al. (1979)
147	Me_4Sn	standards	see method No. 77, (a) and (b)	(a) 8 µg (b) 50 µg	see method No. 77	Burns et al. (1980)
148	Me_4Sn	standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
149	Me_4Sn	standards	hplc-electrothermal aas	1 ng	see method No. 80	Glockling (1980)
150	Me_4Sn	standards	hplc-flame aas	11 ng	N_2O-C_2H_2 flame	Burns et al. (1981)
151	Me_4Sn	standards	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)
152	Me_4Sn	standards	hplc-purge-aas with quartz tube furnace	9.6 pg		Burns et al. (1981)
153	Me_4Sn	atmosphere above sediment culture	gc-fid	~18 µg	mdl estimated	Guard et al. (1981)
154	Me_4Sn	standards	gc-ecd and gc-ms			Hallas et al. (1982)
155	Me_4Sn	estuarine water	purged and trapped, then swept into gc-modified fpd	0.02 µg/L for 10 mL samples		Jackson et al (1982)
156	Me_4Sn	standards	gc-fid	10 ng		Tam et al. (1983)
157	$EtSn^{3+}$	$EtSnCl_3$ standards	see method No. 77, (a) and (b)	(a) 16 µg (b) 100 µg		Burns et al. (1980)
158	$EtSn^{3+}$	$EtSnCl_3$ standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
159	$EtSn^{3+}$	$EtSnCl_3$ standards	hplc, then $EtSnH_3$ generation, then electro-thermal aas	1 ng	see method No. 80	Glockling (1980)
160	$EtSn^{3+}$	$EtSnCl_3$ standards	hplc-flame aas	19 ng		Burns et al. (1981)
161	$EtSn^{3+}$	$EtSnCl_3$ standards	gc-aas with quartz tube furnace	1 ng		Burns et al. (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
162	$EtSn^{3+}$	$EtSnCl_3$ standards	hplc, then $EtSnH_3$ generation, then aas with quartz tube furnace	10 pg		Burns et al. (1981)
163	$EtSn^{3+}$	$EtSnCl_3$ standards	gc, then $EtSnH_3$ generation, then aas with quartz tube furnace	2.2 pg		Burns et al. (1981)
164	Et_2Sn^{2+}	microsomal metabolite of Et_3Sn^+	tlc separation and spot identification with 8-hydroxyquinolinesulfonic acid spray		qualitative	Kimmel et al. (1977)
165	Et_2Sn^{2+}	Et_2SnCl_2 standards	Et_2SnH_2 generation, then method No. 36	0.6 ng		Hodge et al. (1979)
166	Et_2Sn^{2+}	Et_2SnCl_2 standards	see method No. 77, (a) and (b)	(a) 12 µg (b) 90 µg	see method No. 77	Burns et al. (1980)
167	Et_2Sn^{2+}	Et_2SnCl_2 standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
168	Et_2Sn^{2+}	Et_2SnCl_2 standards	hplc, then Et_2SnH_2 generation, then electro-thermal aas	1 ng	see method No. 80	Glockling (1980)
169	Et_2Sn^{2+}	water	spectrophotometric determination of 3-hydroxyflavone complex		ε_{385} = 4.1×10^4 L $mole^{-1}$ cm^{-1}	Aldridge and Street (1981)
170	Et_2Sn^{2+}	Et_2SnCl_2 standards	hplc-flame aas	17 ng		Burns et al. (1981)
171	Et_2Sn^{2+}	Et_2SnCl_2 standards	gc-aas with quartz tube furnace	1.1 ng		Burns et al. (1981)
172	Et_2Sn^{2+}	Et_2SnCl_2 standards	hplc, then Et_2SnH_2 generation, then aas with quartz tube furnace	12 pg		Burns et al. (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
173	Et_2Sn^{2+}	Et_2SnCl_2 standards	gc, then Et_2SnH_2 generation, then aas with quartz tube furnace	4.6 pg		Burns et al. (1981)
174	Et_2Sn^{2+}	spiked rat tissues	see method No. 112	0.1-1 ng	92% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)
175	Et_3Sn^+	microsome preparations	tlc separation and spot identification with dithizone spray		qualitative	Kimmel et al. (1977)
176	Et_3Sn^+	Et_3SnCl standard	Et_3SnH generation, then method No. 36	0.7 ng		Hodge et al. (1979)
177	Et_3Sn^+	Et_3SnCl standard	see method No. 77, (a) and (b)	(a) 8 µg (b) 80 µg	see method No. 77	Burns et al. (1980)
178	Et_3Sn^+	Et_3SnCl standard	hplc-rid		acetone-pentane solvent	Glockling (1980)
179	Et_3Sn^+	Et_3SnCl standard	hplc, then Et_3SnH generation, then electrothermal aas	1 ng	see method No. 80	Glockling (1980)
180	Et_3Sn^+	MeOH	ion exchange hplc-gfaas		possible volatilization during dry and ash cycles	Jewett and Brinckman (1981)
181	Et_3Sn^+	MeOH	hplc-dppd			MacCrehan (1981)
182	Et_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex		ε_{385}=1.1x10^4 L mole^{-1} cm^{-1}	Aldridge and Street (1981)
183	Et_3Sn^+	Et_3SnCl standard	hplc-flame aas	16 ng		Burns et al. (1981)
184	Et_3Sn^+	Et_3SnCl standard	gc-aas with quartz tube furnace	1.2 ng		Burns et al. (1981)
185	Et_3Sn^+	Et_3SnCl standard	hplc, then Et_3SnH generation, then aas quartz tube furnace	13.5 pg		Burns et al. (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
186	Et_3Sn^+	Et_3SnCl standard	gc, then Et_3SnH generation, then aas quartz tube furnace	5.3 pg		Burns et al. (1981)
187	Et_3Sn^+	spiked rabbit tissues	homogenization, extraction as Et_3SnCl into EtOAc, partitioning into hexane, then gc-ecd	~1 pg	> 98% recovery at 50 pmole level	Arakawa et al. (1981a)
188	Et_4Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
189	Et_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
190	Et_4Sn	standards	gc-afid			Dressler et al. (1971)
191	Et_4Sn	standards	gc-fid	20 pg	hydrogen-rich flame; linear response over 10^3x	Aue and Hill (1972b)
192	Et_4Sn	standards	gc-fpd	10 ng	linear response to 10^4 ng	Aue and Hill (1972a)
193	Et_4Sn	standards	(a) gc-fpd (air-rich)	5 ng		Aue and Hill (1973)
			(b) gc-fpd (hydrogen-rich)	5 ng		
			(c) gc-fid (hydrogen-rich)	10 pg		
194	Et_4Sn	standards	gc-modified-fpd	30 pg	filterless	Aue and Hastings (1973)
195	Et_4Sn	standards	see method No. 77, (a) and (b)	(a) 8 µg (b) 50 µg	see method No. 77	Burns et al. (1980)
196	Et_4Sn	standards	gc-modified-fpd	≤ 50 pg	610 nm optical filter; electronic filter enhanced sensitivity by ~4x	Kapila and Vogt (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
197	Et_4Sn	standards	hplc-rid		acetone-pentane solvent	Glockling (1980)
198	Et_4Sn	standards	hplc-electrothermal aas	1 ng	see method No. 80	Glockling (1980)
199	Et_4Sn	standards	gc-plasma aes			Estes et al. (1980)
200	Et_4Sn	rabbit tissues	homogenization, extraction with hexane, gc-fid	10 ng	100% recovery from tissues spiked at 85 nmole level	Arakawa et al. (1981b)
201	Et_4Sn	standards	hplc-flame aas	11 ng		Burns et al. (1981)
202	Et_4Sn	standards	gc-aas with quartz tube furnace	1.4 ng		Burns et al. (1981)
203	Et_4Sn	standards	hplc-purge-aas with quartz tube furnace	14 pg		Burns et al. (1981)
204	Et_4Sn	standards	capillary gc-plasma aes	6 pg	linear range 10^3	Estes et al. (1982)
205	Pr_2Sn^{2+}	microsomal metabolite of Pr_3Sn^+	tlc separation and spot identification with 8-hydroxyquinolinesulfonic acid spray		qualitative	Kimmel et al. (1977)
206	Pr_2Sn^{2+}	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
207	Pr_2Sn^{2+}	MeOH	gfaas	12-21 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
208	Pr_2Sn^{2+}	water	spectrophotometric determination of 3-hydroxyflavone complex		ε_{385}=4.2x10^3 Lmole^{-1} cm^{-1}	Aldridge and Street (1981)
209	Pr_2Sn^{2+}	spiked rat tissues	see method No. 112	0.1-1 ng	95% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)
210	Pr_3Sn^+	MeOH	hplc-gfaas			Brinckman et al. (1977)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
211	Pr_3Sn^+	microsome preparations	tlc separation and spot identification with dithizone spray		qualitative	Kimmel et al. (1977)
212	Pr_3Sn^+	NaOH	ion exchange hplc-gfaas		possible volatilization during dry and ash cycles	Jewett and Brinckman (1981)
213	Pr_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex		$\varepsilon_{385}=1.2\times10^4$ Lmole^{-1}cm^{-1}	Aldridge and Street (1981)
214	Pr_3Sn^+	spiked rabbit tissues	homogenization, extraction as Pr_3SnCl into EtOAc, partitioning into hexane, then gc-ecd	~ 1 pg	> 96% recovery at 50 pmole level	Arakawa et al. (1981a)
215	Pr_4Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
216	Pr_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
217	Pr_4Sn	standards	gc-modified fpd	0.2 pg	filterless; linear range 10^3	Aue and Flinn (1977)
218	Pr_4Sn	standards	gc-modified fpd	<50 pg	610 nm optical filter; electronic filter enhanced sensitivity by ~4 times	Kapila and Vogt (1980)
219	Pr_4Sn	NaOH	gfaas	35-76 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
220	Pr_4Sn	standards	gc-modified fpd	0.04 pg	similar to method No. 204, but with quartz wool plug positioned above flame; linear range > 10^3	Aue and Flinn (1980)
221	Pr_4Sn	standards	gc-plasma aes			Estes et al. (1980)
222	Pr_4Sn	rabbit tissues	homogenization, extraction with hexane, gc-fid	10 ng	100% recovery from tissues spiked at 85 nmole level	Arakawa et al. (1980)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
223	Pr_4Sn	standards	capillary gc-plasma aes	6 pg	linear range 10^3	Estes et al. (1982)
224	$i\text{-}Pr_4Sn$	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
225	$i\text{-}Pr_4Sn$	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
226	$BuSn^{3+}$	$BuSnBr_3$ in Et_2O	Grignard conversion to $BuMe_3Sn$, then gc-tcd			Steinmeyer et al. (1965)
227	$BuSn^{3+}$	standards	Grignard conversion to $BuPr_3Sn$, then gc-tcd		qualitative	Jitsu et al. (1969)
228	$BuSn^{3+}$	microsomal metabolite of Bu_3Sn^+	tlc seperation and spot identification with 8-hydroxyquinolinesulfonic acid spray		qualitative	Kimmel et al. (1977)
229	$BuSn^{3+}$	water	extraction with 0.05% tropolone in C_6H_6 or $CHCl_3$, Grignard derivatization to $BuMe_3Sn$, then gc-ms		70-90% recovery at 1 mg/L level; $BuSn^{3+}$ in water probably adsorbs to glass	Meinema et al. (1978)
230	$BuSn^{3+}$	fresh water	$BuSnH_3$ generation, then method No. 36	0.9 ng		Hodge et al. (1979)
231	$BuSn^{3+}$	pure and fresh water	extraction with tropolone in C_6H_6, Grignard derivatization to $BuPe_3Sn$, then gc-modified-fpd	100 pg	95-100% recovery from water at 10 mg/L level	Maguire and Huneault (1981)
232	$BuSn^{3+}$	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 230	0.5 ng	linear range over 0.05-1 µg/L for 100 mL sample	Boettner et al. (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
233	$BuSn^{3+}$	"artificial tap water" extracts of new PVC and CPVC pipe	extraction with tropolone in C_6H_6, Grignard derivatization to $BuPe_3Sn$, then gc-fid	1.5-3 µg/L (1 L samples)		Boettner et al. (1981)
234	$BuSn^{3+}$	bacterial and fungal cultures	see method No. 229			Barug (1981)
235	$BuSn^{3+}$	estuarine water	method No. 54 with $BuSnH_3$ species	0.02 µg/L with 10 mL sample		Jackson et al. (1982)
236	$BuSn^{3+}$	marine algae	method No. 88 for $BuSnH_3$ species			Ishii (1982)
237	$BuSn^{3+}$	benzene	method No. 56			Imura and Suzuki (1983)
238	$BuSn^{3+}$	sediment	see method No. 57 with $BuPe_3Sn$ species	5 µ/kg with 1 g samples	see method No. 57	Maguire (1984)
239	$BuSn^{3+}$	water	see method No. 58 with $BuPe_3Sn$ species	~110 pg	see method No. 58	Maguire and Tkacz (1983)
240	Bu_2Sn^{2+}	$CHCl_3$	spectrophotometric determination of diphenylcarbazone complex	3 µg	can be determined in presence of $BuSn^{3+}$, Bu_3Sn^+ and Bu_4Sn	Skeel and Bricker (1961)
241	Bu_2Sn^{2+}	Bu_2SnBr_2 in Et_2O	Grignard conversion to Bu_2Me_2Sn, then gc-tcd			Steinmayer et al. (1965)
242	Bu_2Sn^{2+}	standards	Grignard conversion to Bu_2Pr_2Sn, then gc-tcd			Jitsu et al. (1969)
243	Bu_2Sn^{2+}	standards	i.r. spectra		qualitative	Udris (1971)
244	Bu_2Sn^{2+}	dibutyltin diisurate in poultry feeds	extracted with $CHCl_3$, transferred to MeOH, then flame aas	10 mg/L of analyte to be aspirated	quantitative recovery at 0.02% concentration	George et al. (1973)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
245	Bu_2Sn^{2+}	sea water	extraction with CCl_4, oxidation to Sn^{4+}, then spectrophotometric determination of phenylfluorone complex	0.01 mg/L		Mor et al. (1973)
246	Bu_2Sn^{2+}	microsomal metabolite of Bu_3Sn^+	tic separation and spot identification with 8-hydroxyquinolinesulfonic acid spray		qualitative	Kimmel et al. (1977)
247	Bu_2Sn^{2+}	water	extraction with 0.05% tropolone in C_6H_6 or $CHCl_3$, Grignard derivatization to Bu_2Me_2Sn, then gc-ms		70-90% recovery at 1mg/L level	Maineme et al. (1978)
248	Bu_2Sn^{2+}	fresh water	Bu_2SnH_2 generation then method No. 36	1.0 ng		Hodge et al. (1979)
249	Bu_2Sn^{2+}	textiles	extracted with MeOH/ 0.05% HCl, diluted with H_2O, extracted with 4-(2-pyridylazo) resorcinol in CH_2Cl_2, then oxidized, then gfaas			Kojima (1979)
250	Bu_2Sn^{2+}	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
251	Bu_2Sn^{2+}	MeOH	gfaas	13-22 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
252	Bu_2Sn^{2+}	soil	extraction with wet Et_2O /formic acid (98/2, v/v), tlc and scintillation counting		70% recovery	Barug and Vonk (1980)
253	Bu_2Sn^{2+}	NaOH	ion-exchange hplc-gfaas	0.2 mg/L		Jewett and Brinckman (1981)
254	Bu_2Sn^{2+}	water	spectrophotometric determination of 3-hydroxyflavone complex		$\epsilon_{385}=4.0\times10^4$ $Lmole^{-1}cm^{-1}$	Aldridge and Street (1981)
255	Bu_2Sn^{2+}	pure and fresh water	method No. 231 with Bu_2Pe_2Sn	120 pg	> 95% recovery at 10 mg/L level	Maguire and Hunesult (1981)
256	Bu_2Sn^{2+}	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 230 with Bu_2SnH_2 generation	0.5 ng	linear range 0.05-1 µg/L for 100 mL sample	Boettner et al. (1981)
257	Bu_2Sn^{2+}	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 233 with Bu_2Pe_2Sn species	1.5-3 µg/L (1 L sample)		Boettner et al. (1981)
258	Bu_2Sn^{2+}	bacterial and fungal cultures	see method No. 229			Barug (1981)
259	Bu_2Sn^{2+}	estuarine water	see method No. 54 with Bu_2SnH_2 species	0.04 µg/L with 10 mL samples		Jackson et al. (1982)
260	Bu_2Sn^{2+}	PVC	^{119m}Sn Mossbauer spectroscopy			Brooks et al. (1982)
261	Bu_2Sn^{2+}	fishing nets	dppd	14 µg/L		Hasebe et al. (1982)
262	Bu_2Sn^{2+}	spiked rat tissue	see method No. 112	0.1-1 ng	98% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
263	Bu_2Sn^{2+}	benzene	see method No. 56			Imura and Suzuki (1983)
264	Bu_2Sn^{2+}	sediment	see method No. 57 with Bu_2Pe_2Sn species	5 µg/kg with 1 g samples	see method No. 57	Maguire (1984)
265	Bu_2Sn^{2+}	water	see method No. 58 with Bu_2Pe_2Sn species	120-140 pg		Maguire and Tkacz (1983)
266	Bu_3Sn^+	Bu_3SnBr in Et_2O	Grignard conversion to Bu_3MeSn, then gc-tcd			Steinmeyer et al. (1965)
267	Bu_3Sn^+	standards	Grignard conversion to Bu_3PrSn, then gc-tcd			Jitsu et al. (1969)
268	Bu_3Sn^+	sea water	method No. 245	0.01 mg/L		Mor et al. (1973)
269	Bu_3Sn^+	50% (v/v) EtOH	dppd	29 µg/L		Fleet and Fouzder (1975)
270	Bu_3Sn^+	acidic aqueous solution	asv after dealkylation under UV light	0.01 mg/L		Woggon and Jehle (1975)
271	Bu_3Sn^+	MeOH	hplc-gfaas			Brinckman et al. (1977)
272	Bu_3Sn^+	Bu_3SnH standards	gc-modified fpd	1 pg	see method No. 217	Aue and Flinn (1977)
273	Bu_3Sn^+	microsome preparations	tlc separation and spot identification with 8-hydroxyquinoline spray		qualitative	Kimmel et al. (1977)
274	Bu_3Sn^+	water	extraction with 0.05% tropolone in C_6H_6 or $CHCl_3$, Grignard derivatization to Bu_3MeSn, then gc-ms		70-90% recovery at 1 mg/L level	Maineme et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
275	Bu_3Sn^+	soil	radiolabelled compound extracted with acetic acid, partitioned into hexane, then tlc and scintillation counting		% recovery not stated	Sheldon (1978)
276	Bu_3Sn^+	standards	Bu_3SnH generation, then method No. 36	2.0 ng		Hodge et al. (1979)
277	Bu_3Sn^+	textiles	see method No. 249			Kojima (1979)
278	Bu_3Sn^+	mice tissues	radiolabelled compound detected by scintillation counting after tissues solubilized with "Unisol"; blood and feces digested with $HClO_4$-H_2O_2	1.5 ng	% recovery not stated	Evans et al. (1979)
279	Bu_3Sn^+	water (spiked)	extracted with hexane, oxidized with H_2SO_4-H_2O_2 then spectrophotometric determination of phenylfluorone complex	0.1 µg	linear response to 4 µg	Sherman and Carlson (1980)
280	Bu_3Sn^+	MeOH	gfaas	8-22 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
281	Bu_3Sn^+	soil	see method No. 252		% recovery not stated	Berug and Vonk (1980)
282	Bu_3Sn^+	MeOH	ion exchange hplc-gfaas	0.16 mg/L		Jewett and Brinckman (1981)
283	Bu_3Sn^+	MeOH	hplc-dppd			MacCrehan (1981)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
284	Bu_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex		$\varepsilon_{385}=1.2\times10^4$ $Lmole^{-1}cm^{-1}$	Aldridge and Street (1981)
285	Bu_3Sn^+	spiked rabbit tissues	homogenization, extractions as Bu_3SnCl into EtOAc, partitioning into hexane, then gc-ecd	~1 pg	> 96% recovery at 10 mg/L level	Arakawa et al. (1981a)
286	Bu_3Sn^+	pure and fresh water	method No. 231 with Bu_3PeSn	150 pg	> 96% recovery at 10 mg/L level	Maguire and Huneault (1981)
287	Bu_3Sn^+	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 230 with Bu_3SnH generation	0.5 ng	linear range 0.01-1 µg/L for 100 mL sample	Boettner et al. (1981)
288	Bu_3Sn^+	"artificial tap water" extracts of new PVC and CPVC pipe	see method No. 233 with Bu_3PeSn species	1.5-3 µg/L (1 L samples)		Boettner et al. (1981)
289	Bu_3Sn^+	bacterial and fungal cultures	see method No. 229			Barug (1981)
290	Bu_3Sn^+	fishing nets	dppd	64 µg/L		Hasebe et al. (1982)
291	Bu_3Sn^+	estuarine bacterial cultures	cells collected by centrifugation, then HNO_3 oxidation, then gfaas			Blair et al. (1982)
292	Bu_3Sn^+	bound to bacterial cells	cells centrifuged, extracted with MeOH, then ion exchange hplc-gfaa			Blair et al. (1982)
293	Bu_3Sn^+	sea water	dpasv	5 µ/L		Kenis and Zirino (1983)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
294	Bu_3Sn^+	benzene	see method No. 56			Imura and Suzuki (1983)
295	Bu_3Sn^+	sediment	see method No. 57 with Bu_3PeSn species	5 µg/kg with 1 g samples	see method No. 57	Maguire (1984)
296	Bu_3Sn^+	water	see method No. 58 with Bu_3PeSn species	150 pg		Maguire and Tkacz (1983)
297	TBTO	air	glass fibre filters extracted with MIBK, then flame-aas			Jeltes (1969)
298	Bu_4Sn	standards	gc-tcd			Steinmeyer et al. (1965)
299	Bu_4Sn	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)
300	Bu_4Sn	standards	gc-tcd		extended previous work to temperature programming	Putnam and Pu (1965b)
301	Bu_4Sn	standards	gc-tcd			Jitsu et al. (1969)
302	Bu_4Sn	standards	gc-fpd	10 ng	linear response to 10^4 ng	Aue and Hill (1972a)
303	Bu_4Sn	standards	gc-modified fpd	1 pg	filterless; linear range 10^3	Aue and Flinn (1977)
304	Bu_4Sn	standards	gc-modified fpd	<50 pg	see method No. 205	Kapila and Vogt (1980)
305	Bu_4Sn	MeOH	gfaas	15-23 pg	Zr-treated furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
306	Bu_4Sn	rabbit tissues	homogenization, extraction with hexane, then gc-fid	10 ng	> 96% recovery of tissues spiked at 85 nmole level	Arakawa et al. (1981b)
307	$I\text{-}Bu_4Sn$	standards	gc-tcd		determined retention times on 3 stationary phases	Putnam and Pu (1965a)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins*

Number	Compound	Medium	Method	MDL	Comments	Reference
308	i-Bu_4Sn	standards	gc-tcd		extended previous work to temperature programming; this work and method No. 307 also dealt with Me_3EtSn, Me_3PrSn, Me_3i-PrSn, Me_3t-BuSn, Me_3CySn, Me_3VlSn, Me_3PhSn and Vl_4Sn	Putnam and Pu (1965b)
309	Pe_3Sn^+	microsome preparations	tlc separation and spot identification with 8-hydroxyquinoline spray		qualitative	Kimmel et al. (1977)
310	Hex_3Sn^+	microsome preparations	tlc separation and spot identification with 8-hydroxyquinoline spray		qualitative	Kimmel et al. (1977)
311	$OctSn^{3+}$	standards	Grignard conversion to $OctPe_3Sn$, then gc-tcd			Jitsu et al. (1969)
312	$OctSn^{3+}$	standards	Grignard conversion to $OctMe_3Sn$, then gc with tcd or hot wire detector			Neubert and Wirth (1975)
313	$OctSn^{3+}$	standards	Grignard conversion to $OctEt_3Sn$, then gc-tcd			Figge et al. (1977)
314	Oct_2Sn^{2+}	standards	Grignard conversion to Oct_2Pe_2Sn, then gc-tcd			Jitsu et al. (1969)
315	Oct_2Sn^{2+}	standards	i.r. spectra		qualitative	Udris (1971)
316	Oct_2Sn^{2+}	standards	Grignard conversion to Oct_2Me_2Sn, then gc with tcd or hot wire detector			Neubert and Wirth (1975)
317	Oct_2Sn^{2+}	standards	Grignard conversion to Oct_2Et_2Sn, then gc-tcd			Figge et al. (1977)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
318	Oct_2Sn^{2+}	as bis-maleate in EtOH, HOAc and heptane	gfaas	10 µg/L		Varnes and Gaylor (1978)
319	Oct_2Sn^{2+}	spiked rat tissues	see method No. 112	0.1-1 ng	> 96% recovery from tissues spiked at 5 nmole level	Yu and Arakawa (1983)
320	Oct_3Sn^+	standards	Grignard conversion to Oct_3PeSn, then gc-tcd			Jitsu et al. (1969)
321	Oct_3Sn^+	standards	Grignard conversion to Oct_3MeSn, then gc with tcd or hot wire detector			Neubert and Wirth (1975)
322	Oct_3Sn^+	standards	Grignard conversion to Oct_3EtSn, then gc-tcd			Figge et al. (1977)
323	$CySn^{3+}$	residues on apples and pears	fruit extracted with HOAc/hexane solution, which was in turn extracted with HCl and back-extracted with hexane; $CySn^{3+}$ in the HCl phase was oxidized to Sn^{4+} and determined spectrophotometrically as dithiol complex			Getzendaner and Corbin (1972)
324	$CySn^{3+}$	$CySnBr_3$ standards	gc-cd		on-column degradation	Gauer et al. (1974)
325	$CySn^{3+}$	on glass slides and wax-coated glass slides	tlc with spot identification by diphenylthiocarbezone and quantitation by scintillation counting of the radiolabelled spike			Smith et al. (1976)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
326	Cy_2Sn^{2+}	residues on apples and pears	start with method No. 323; Cy_2Sn^{2+} in back-extracted hexane solution transferred to KOH solution, back extracted with hexane and analyzed as in method No. 323			Getzendaner and Corbin (1972)
327	Cy_2Sn^{2+}	residues on strawberries, apples and grapes, and in water	extracted with C_6H_6, converted by HBr to Cy_2SnBr_2, cleaned up and analyzed by gc-cd		80-90% recovery from fruit at 0.1-1 mg/L level; 94% recovery from water at 1 mg/L; on-column degradation or adsorption noted	Geuer et al. (1974)
328	Cy_2Sn^{2+}	on glass slides and wax-coated glass slides	see method No. 325			Smith et al. (1976)
329	Cy_2Sn^{2+}	microsomal metabolite of Cy_3Sn^+	tlc separation and spot identification with 8-hydroxyquinoline spray		qualitative	Kimmel et al. (1977)
330	Cy_2Sn^{2+}	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
331	Cy_2Sn^{2+}	MeOH	gfaas	13-24 pg	Zr-[illegible]od furnaces reduced species-dependent sensitivity	Vickrey et al. (1980b)
332	Cy_3Sn^+	residues on fruit	wet oxidation to Sn^{4+}, then method No. 16	0.2 mgSn		Corbin (1970)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
333	Cy_3Sn^+	residues on apples and pears	start with method No. 326; Cy_3Sn^+ in the hexane solution after KOH extraction is oxidized to Sn^{4+} and analyzed by method No. 323			Getzendaner and Corbin (1972)
334	Cy_3Sn^+	residues on strawberries, apples and grapes, and in water	extracted with C_6H_6, converted by HBr to Cy_3SnBr, cleaned up and analyzed by gc-cd		78-95% recovery from fruit at 0.1-1 mg/L level; 99% recovery from water at 1 mg/L; on-column degradation or adsorption noted	Gauer et al. (1974)
335	Cy_3Sn^+	rat urine, feces, organs, fat and blood	scintillation counting			Blair (1975)
336	Cy_3Sn^+	on glass slides and wax-coated glass slides	see method No. 325			Smith et al. (1976)
337	Cy_3Sn^+	in microsome preparations	tlc		qualitative	Kimmel et al. (1977)
338	Cy_3Sn^+	standards	Grignard conversion to Cy_3PhSn, then gc-fid		Grignard reaction catalyzed by CuCl; yield >95%; linear response from 0.05 to 3 µg	Esposto et al. (1978)
339	Cy_3Sn^+	standards	Grignard conversion to Cy_3EtSn, then gc-ms			Stewart and Cannizzaro (1980)
340	Cy_3Sn^+	NaOH	ion exchange-hplc-gfaa			Jewett and Brinckman (1981)
341	Cy_3Sn^+	as Cy_3SnOH in air	filter samples wet ashed, then Sn^{4+} determined by gfaas			Houk and Beaulieu (1981)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
342	$PhSn^{3+}$	standards	Grignard conversion to $PhPe_3Sn$, then gc-fpd			Jitsu et al. (1969)
343	$PhSn^{3+}$	on glass plate (after photolysis)	detection by tlc with catechol violet spray; quantitation by oxidation to Sn^{4+} followed by spectrophotometric determination of phenylfluorone complex			Chapman and Price (1972)
344	$PhSn^{3+}$	on glass plate (after photolysis)	tlc with uv-fluorescence		qualitative	Barnes et al. (1973)
345	$PhSn^{3+}$	standards	fluorescence determination of 3-hydroxyflavone complex		λ_{ex}=470 nm λ_{em}=490 nm	Vernon (1974)
346	$PhSn^{3+}$	water	extracted with tropolone in $CHCl_3$, determined spectrophotometrically with a number of complexing agents, or by gc-fid as $PhSnCl_3$		low yield implied for conversion to $PhSnCl_3$	Freitag and Bock (1974a)
347	$PhSn^{3+}$	on sugar beet leaves and in rats (radiolabelled Ph_3Sn^+ spike)	see method No. 346 with scintillation counting			Freitag and Bock (1974b)
348	$PhSn^{3+}$	standards	fluorescence determination of 3-hydroxyflavone complex		complex is unstable under laboratory light; λ_{ex}=415 nm; λ_{em}=490nm	Blunden and Chapman (1978)

Cont'd...../

TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
349	$PhSn^{3+}$	water	extracted with CH_2Cl_2, transferred to hexane, $PhSnH_3$ generated and analyzed by gc-ecd		poor recoveries	Soderquist and Crosby (1978)
350	$PhSn^{3+}$	standards	$PhSnH_3$ generation, then method No. 36	1.0 ng		Hodge et al. (1979)
351	$PhSn^{3+}$	standards	Grignard conversion to $PhMe_3Sn$, then gc-fpd		"nearly quantitative" conversion; no optical filter	Wright et al. (1979)
352	$PhSn^{3+}$	spiked in estuarine water	method No. 34 with $PhSnH_3$ species	0.02 µg/L with 10 mL samples		Jackson et al. (1982)
353	Ph_2Sn^{2+}	standards	Grignard conversion to Ph_2Pe_2Sn, then gc-tcd			Jitsu et al. (1969)
354	Ph_2Sn^{2+}	on glass plate (after photolysis)	see method No. 343			Chapman and Price (1972)
355	Ph_2Sn^{2+}	on glass plate (after photolysis)	see method No. 344		qualitative	Barnes et al. (1973)
356	Ph_2Sn^{2+}	standards	fluorescence determination of 3-hydroxyflavone complex		λ_{ex}=465 nm, λ_{em}=495nm	Vernon (1974)
357	Ph_2Sn^{2+}	water	extracted with a number of complexing agents in different organic solvents and determined spectrophotometrically with a number of complexing agents, or by gc-fid as Ph_2SnCl_2		low yield implied for conversion to Ph_2SnCl_2	Freitag and Bock (1974a)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
358	Ph_2Sn^{2+}	on sugar beet leaves and in rats (radio-labelled Ph_3Sn^+ spike)	see method No. 357 with scintillation counting			Freitag and Bock (1974b)
359	Ph_2Sn^{2+}	standards	fluorescence determinations of 3-hydroxy-flavone complex		see method No. 348	Blunden and Chapman (1978)
360	Ph_2Sn^{2+}	water	see method No. 349 with Ph_2SnH_2		poor recoveries	Soderquist and Crosby (1978)
361	Ph_2Sn^{2+}	standards	Grignard conversion to Ph_2Me_2Sn, then gc-fpd		"nearly quantitative" concession; no optical filter	Wright et al. (1979)
362	Ph_3Sn^+	standards	Grignard conversion to Ph_3PeSn, then gc-tcd			Jitsu et al. (1969)
363	Ph_3Sn^+	potatoes	extraction with MeCN, then asv	3.5 µg/L for pure standards		Booth and Fleet (1970)
364	Ph_3Sn^+	on glass plates	see method No. 343			Chapman and Price (1972)
365	Ph_3Sn^+	sea water	see method No. 245			Mar et al. (1973)
366	Ph_3Sn^+	soil (radio-labelled spike)	extracted with hot organic solvents, then scintillation counting		recoveries diminished with soil-contact time	Barnes et al. (1973)
367	Ph_3Sn^+	standards	fluorescence determination of 3-hydroxyflavone complex	0.16 µgSn	λ_{ex}=415 nm, λ_{em}=497 nm	Vernon (1974)
368	Ph_3Sn^+	water	extracted with $CHCl_3$ or CH_2Cl_2 with spectro-photometric determination of dithizone complex, or by gc-fid as Ph_3SnCl			Freitag and Bock (1974a)

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TABLE I (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
369	Ph_3Sn^+	on sugar beet leaves in rats (radiolabelled spike)	see method No. 368 with scintillation counting			Freitag and Bock (1974b)
370	Ph_3Sn^+	50% (v/v) EtOH	dppd	35 µg/L		Fleet and Fouzder (1975)
371	Ph_3Sn^+	acidic aqueous solution	asv after dealkylation under uv light	0.01 mg/L		Hoggan and Jahic (1975)
372	Ph_3Sn^+	NaOH	hplc-gfaas			Brinkman et al. (1977)
373	Ph_3Sn^+	standards	Grignard conversion to Ph_4Sn, then gc-fid		Grignard reaction catalyzed by CuCl; yield >95%; linear response from 0.05 to 3 µg	Esposto et al. (1978)
374	Ph_3Sn^+	technical material and formulations	extracted into acetone, cleaned up with alumina, then titrated potentiometrically		interlaboratory comparison study	Litan et al. (1977)
375	Ph_3Sn^+	in triphenyltin-manganous ethylene-1,2-bisdithiocarbamate (Fentin-Maneb) formulations in toluene	Grignard conversion to Ph_3BuSn, then gc-fid or gc-tcd		interlaboratory comparison study	Masters et al. (1978)
376	Ph_3Sn^+	distilled, tap, canal and synthetic sea water (spiked)	extracted with toluene, then fluorescence determination of 3-hydroxyflavone complex		λ_{ex}=415 nm, λ_{em}=495 nm; recoveries varied from 94% at 2 mg/L to 75% at 4 µg/L	Blunden and Chapman (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
377	Ph_3Sn^+	water	see method No. 349 with Ph_3SnH		quantitative recovery at 50 µg/L	Soderquist and Crosby (1978)
378	Ph_3Sn^+	soil	radiolabelled compound extracted with acetic acid, partitioned into hexane, then tlc and scintillation counting		%recovery not stated	Sheldon (1978)
379	Ph_3Sn^+	standards	Grignard conversion to Ph_3MeSn, then gc-fpd	10 pg	linear response to 100 ng; "nearly quantitative" conversion; no optical filter	Wright et al. (1979)
380	Ph_3Sn^+	seaweeds with radiolabelled spike	seaweed digested with a quaternary ammonium hydroxide in toluene, then scintillation counting			Callow et al. (1979)
381	Ph_3Sn^+	*Daphnia magna* in water with radiolabelled Ph_3Sn^+	dissolved *Daphnia* in HNO_3, neutralized, then scintillation counting			Flienko and Isakova (1979)
382	Ph_3Sn^+	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
383	Ph_3Sn^+	MeOH	gfaas	13-19 pg		Vickrey et al. (1980b)
384	Ph_3Sn^+	standards	Grignard conversion to Ph_3MeSn or Ph_3EtSn, then gc-ms			Stewart and Cannizzaro (1980)
385	Ph_3Sn^+	soil	extraction as Ph_3SnCl with CH_2Cl_2, transfer to acetone, then gc-ms			Kuwahara et al. (1980)

Cont'd...../

TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
386	Ph_3Sn^+	MeOH	ion exchange-hplc-gfaa			Jewett and Brinckman (1981)
387	Ph_3Sn^+	MeOH	hplc-dppd		linear response from 0.35-35 mg/L	MacCrehan (1981)
388	Ph_3Sn^+	water	spectrophotometric determination of 3-hydroxyflavone complex		ε_{385}=1.5x10^4 Lmole^{-1}cm^{-1}	Aldridge and Street (1981)
389	Ph_3Sn^+	Ph_3SnCl standards	flame aas		air/H_2 flame; comparisons made with other flames and atomic emission	Marr and Anwar (1982)
390	Ph_4Sn	standards	gc-fpd	1 pg	filterless; linear range - 10^4	Aue and Flinn (1977)
391	Ph_4Sn	standards	gc-fpd	10 pg	no optical filter	Wright et al. (1979)
392	Ph_4Sn	MeOH/water (97.5/2.5, v/v)	hplc-gfaas		see method No. 60	Vickrey et al. (1980a)
393	Ph_4Sn	MeOH	gfaas	8-18 pg		Vickrey et al. (1980b)
394	Ph_4Sn	toluene	size exclusion chromatography with icp-aes		method also used for Vi_4Sn and two phenyl organotins containing acetylenic bonds	Hausler and Taylor (1981a)
395	Ph_4Sn	standards	flame aas		air/H_2 flame; comparisons made with other flames and atomic emission; method also used for Vi_4Sn, hexaphenyldistin and a number of uncommon organotin compounds with Sn-S-phenyl linkages	Marr and Anwar (1982)

Cont'd...../

TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
396	hexakis (2-methyl-2-phenyl-propyl) distan-noxane (Vendex)	apples, oranges and tea leaves	homogenize, extract with Et_2O/HOAc, clean up on silica gel column, then glass	5 ng	can also determine two degradation products, tetrakis (2-methyl-2-phenyl-propyl) distannoxane and 2-methyl-2-phenylpropyl stannoic acid	Sano et al. (1979)
397	hexakis (2-methyl-2-phenyl-propyl) distan-noxane (Vendex)	standards	Grignard conversion to methyltri-(2-methyl-2-phenylpropyl) tin, then gc-ms			Stewart and Cannizzaro (1980)
398	12, 12-dimethyl-12-stanna-hexa-decanoic acid	membranes	scanning electron micro-scope		compound prepared and added to culture of Acholeplasma laidlawii to examine its potential as an ultra-structural probe for the lipid organization of bio-membranes	Andrews et al. (1978)

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TABLE 1 (Cont'd): Analytical Methods for Tin and Organotins[a]

Number	Compound	Medium	Method	MDL	Comments	Reference
399	oxidation products of t-butyl esters of tin-substituted peroxycarboxylic acids	standards	ic-uv			Makarenko and Yashin (1983)
400	methacrylate polymers containing Bu_3Sn- and Pr_3Sn-ester linkages; and Cy_3Sn-ethyl orthopentasilicate	mineral spirits (Stoddard solvent)	size-exclusion hplc-gfaas for polymers; rbp-gfaas for silicate			Parks et al. (1979) and Parks et al. (1983)

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* **Abbreviations**

aas	atomic absorption spectrophotometry
aes	atomic emission spectroscopy
afid	alkaline flame ionization detector
Ar	argon
asv	anodic stripping voltammetry
Bu	n-butyl
C_2H_2	acetylene
C_6H_6	benzene
CH_2Cl_2	dichloromethane
$CHCl_3$	chloroform
CCl_4	carbon tetrachloride
cd	Coulson conductivity detector
CPVC	chlorinated polyvinyl chloride
Cy	cyclohexyl
dpasv	differential pulse anodic stripping voltammetry
dppd	differential pulse polarographic detector
ecd	electron capture detector
edl	electrodeless discharge lamp
Et	ethyl
EtOH	ethyl alcohol
EtOAc	ethyl acetate
Et_2O	diethyl ether
fid	flame ionization detector
fpd	flame photometric detector
gc	gas chromatography
gc-ms	gas chromatography-mass spectrometry
gfaas	graphite furnace atomic absorption spectrophotometry
H_2	hydrogen
HNO_3	nitric acid
HOAc	acetic acid
hplc	high pressure liquid chromatography
i	iso-
icp-aes	inductively-coupled plasma-atomic emission spectroscopy
ir	infrared
mdl	minimum detectable level
Me	methyl
MeCN	acetonitrile
MeOH	methanol
MHz	megahertz
MIBK	methylisobutylketone
ms	mass spectrometry
N_2O	nitrous oxide
NaOH	sodium hydroxide
Oct	n-octyl
Pe	n-pentyl
Ph	phenyl
Pr	n-propyl
PVC	polyvinyl chloride
rbp	reverse bonded phase
rid	refractive index detector
tcd	thermal conductivity detector
TBTO	bis (tri-n-butyltin) oxide
tlc	thin layer chromatography
uv	ultraviolet
Vi	vinyl

TABLE 2: Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	silicic rocks	3.6 mg/kg average	Japan	Hamaguchi *et al.* (1964)
	"intermediate" rocks	1.5 mg/kg average	Japan	Hamaguchi *et al.* (1964)
	mafic rocks	0.9 mg/kg average	Japan	Hamaguchi *et al.* (1964)
	ultramafic rocks	0.35mg/kg average	Japan	Hamaguchi *et al.* (1964)
	red clays	4.9 mg/kg average	Pacific Ocean near Japan	Hamaguchi *et al.* (1964)
	globigerina ooze	1.5 mg/kg average	Pacific Ocean near Japan	Hamaguchi *et al.* (1964)
	volcanic muds	1.4 mg/kg average	Pacific Ocean near Japan	Hamaguchi *et al.* (1964)
	seawater	0.81 µg/L	Pacific Ocean	Hamaguchi *et al.* (1964)
	marine animals	1.7 mg/kg average	Tokyo Bay (*Metapenaeus joyneri*, *Watosenia scintillians* and *Meretrix meretric cusoria*)	Hamaguchi *et al.* (1964)
	estuarine water	0.02-0.04 µg/kg	general	Smith and Burton (1972)
	shelf water	0.02-0.04 µg/kg	general	Smith and Burton (1972)
	surface Atlantic water	0.009 µg/kg	general	Smith and Burton (1972)
	ultramafic rocks	0.8 mg/kg	general	Smith and Burton (1972)
	basalts	1.7 mg/kg	general	Smith and Burton (1972)
	silicic rocks	2.5 mg/kg	general	Smith and Burton (1972)
	red clays	3.4 mg/kg	general	Smith and Burton (1972)
	amphibolites	1.2 mg/kg	general	Smith and Burton (1972)
	air	n.d.-0.3 µg/m^3	general	World Health Organization (1980)
		up to 5 µg/m^3	vicinity of industrial emissions	World Health Organization (1980)
	soil	<200 mg/kg	general	World Health Organization (1980)
		up to 1000 mg/kg	regions of tin - containing minerals	World Health Organization (1980)
	igneous rocks	1.7 mg/kg	average	Iverson and Brinkman (1978)
	shales	6 mg/kg	average	Iverson and Brinkman (1978)
	food	~1 mg/kg	diet of fresh meat, cereals vegetables	World Health Organization (1980)
	drinking water	n.d.-30 µg/L	general	World Health Organization (1980)
		0.005-0.013 µg/L		Braman and Tompkins (1979)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	fresh water	n.d.-0.73 µg/L	Florida	Braman and Tompkins (1979)
		30-90 µg/L	N.O. polder - Netherlands	Leeuwangh et al. (1976)
		30-90 µg/L	Delft, Netherlands	Leeuwangh et al. (1976)
		<1-17 µg/L	Malaysia	Peterson et al. (1976)
		4×10^{-3} µg/L	general	Iverson and Brinckman (1978)
	estuarine water	0.01-0.38 µg/L	Florida	Braman and Tompkins (1979)
		<2 µg/L	Chesapeake Bay, U.S.A.	Hallas and Cooney (1981)
		0.2-20 µg/L	Baltimore Harbor, U.S.A.	Jackson et al. (1982)
		2.2-3.9 µg/L	Malaysia	Peterson et al. (1976)
	sea water	9×10^{-3} µg/L	North Atlantic Ocean (average)	Iverson and Brinckman (1978)
		2.5 µg/L	Malaysia	Peterson et al. (1976)
		3 µg/L	general	World Health Organization (1980)
		0.002-0.085 µg/L	around Florida	Braman and Tompkins (1979)
	rain water	0.004-0.045 µg/L	Florida	Braman and Tompkins (1979)
	human urine	0.56-1.6 µg/L	Florida	Braman and Tompkins (1979)
	sewage treatment plant outfall	152 µg/L	Chesapeake Bay, U.S.A.	Hallas and Cooney (1981)
	sediment	1-20 mg/kg dry weight	Narragansett Bay, U.S.A.	Hodge et al. (1979)
		n.d.-100 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerdi (1980)
		1-4 mg/kg	N.O. polder, Netherlands	Leeuwangh et al. (1976)
		2 mg/kg	Delft, Netherlands	Leeuwangh et al. (1976)
		240 mg/kg	Baltimore Harbor	Hallas and Cooney (1981)
		0.8-7.9 mg/kg	Chesapeake Bay	Hallas and Cooney (1981)
		8-450 mg/kg	Germany	Schramel et al. (1973)
		5-14 mg/kg dry weight	Savannah River estuary, U.S.A.	Seidel et al. (1980)
		1-25 mg/kg dry weight	Lake Michigan	Seidel et al. (1980)
		8-29 mg/kg dry weight	Palace moat, Tokyo	Seidel et al. (1980)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
total Sn	sediment	2 mg/kg at 55 cm core depth, roughly constant to 20 cm, then increasing to 26 mg/kg at 4 cm depth	Lake Michigan	Goldberg et al. (1981)
	municipal sewage sludges	111-492 mg/kg dry weight	U.S.A.	Fuhr et al. (1976)
	coal fly ash	4.3×10^{-3} mg/kg	Japan	Imura and Suzuki (1981)
	thallophyta (primarily algae and "plankton")	3-5 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerdi (1980)
		0.5-1.1 mg/kg dry weight	St. Vincent's Gulf, Australia	Maher (1982)
		0.03-1.1 mg/kg dry weight	California	Hodge et al. (1979)
		1.5-3.2 mg/kg	Gulf of Naples, Italy	Smith (1970)
	embryophyta (largely terrestrial plants and macrophytes)	4-12.8 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerdi (1980)
		0.2-1.5 mg/kg dry weight	Germany	Schramel et al. (1973)
		1.5-32 mg/kg dry weight	Malaysia	Peterson et al. (1976)
		8.4-2165 mg/kg dry weight	Malaysia (near Sn smelter)	Peterson et al. (1976)
	coelenterata	1.2 mg/kg	Gulf of Naples, Italy	Smith (1970)
	pelecypoda (molluscs, oysters)	<0.01 mg/kg dry weight	St. Vincent's Gulf, Australia	Maher (1982)
		0.03-1.25 mg/kg dry weight	St. Vincent's Gulf, Australia	Maher (1982)
		<0.15-0.95 mg/kg wet weight	France	Alzieu et al. (1980)
		0.85-110 mg/kg	France	Alzieu et al. (1982)
		<0.03-1.6 mg/kg	Gulf of Naples, Italy	Smith (1970)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
	gastropoda	0.02-0.13 mg/kg	N.O. polder, Netherlands	Leeuwangh et al. (1976)
	crustacea	0.06-3.0 mg/kg	Gulf of Naples, Italy	Smith (1970)
	insecta	0.04 mg/kg	N.O. polder, Netherlands	Leeuwangh et al. (1976)
	echinodermata	<0.03-0.96 mg/kg	Gulf of Naples, Italy	Smith (1970)
	tunicata	0.5-15 mg/kg	Gulf of Naples, Italy	Smith (1970)
	osteichthyes (fish)	<0.01-0.02 mg/kg dry weight	St. Vincent's Gulf, Australia	Maher (1982)
		0.4-8.4 mg/kg dry weight	Lake Leman, Switzerland	Dogan and Haerdi (1980)
		190-630 mg/kg	N.O. polder, Netherlands	Leeuwangh et al. (1976)
		23-31 mg/kg	Delft, Netherlands	Leeuwangh et al. (1976)
		n.d.-0.6 mg/kg dry weight	Germany	Schramel et al. (1973)
		<0.03 mg/kg	Gulf of Naples, Italy	Smith (1970)
Inorganic Sn	drinking water	0.002 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	<0.0003-0.73 µg/L	Florida	Braman and Tompkins (1979)
		0.084-0.490 µg/L	Lake Michigan, U.S.A.	Hodge et al. (1979)
		n.d.-0.12 µg/L	rivers in southeastern U.S.A.	Byrd and Andreae (1982)
		0.02 µg/L	Rhine River, Germany	Byrd and Andreae (1982)
		0.001 µg/L	Main River, Germany	Byrd and Andreae (1982)
		n.d.-50 µg/L	rivers and lakes in Ontario, Canada	Maguire et al. (1982)
	fresh water surface microlayer	n.d.-633 µg/L	rivers and lakes in Ontario, Canada	Maguire et al. (1982)
	estuarine water	<0.0003-0.567 µg/L	Florida	Braman and Tompkins (1979)
	sea water	<0.0003-0.62 µg/L	Florida	Braman and Tompkins (1979)
		0.0003-0.38 µg/L	California	Hodge et al. (1979)
		3-7770 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	rain water	0.003-0.041 µg/L	Florida	Braman and Tompkins (1979)
	human urine	0.4-1.1 µg/L	Florida	Braman and Tompkins (1979)
	rain water	1-3 ng/L	La Jolla, U.S.A.	Trugrul et al. (1983)
		5 ng/L	La Jolla, U.S.A.	Trugrul et al. (1983)
	sediment	0.08-5.13 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
Inorganic Sn	sediment	n.d.-11 mg/kg dry weight	California coast	Seidel et al. (1980)
	shell samples	< 0.00005-0.0029 mg/kg	Florida	Braman and Tompkins (1979)
	invertebrates	0.014-0.052 mg/kg dry weight	San Diego Bay, California	Seidel et al. (1980)
	algae	n.d.-1.28 mg/kg dry weight	San Diego Bay, California	Seidel et al. (1980)
		0.016-0.117 mg/kg dry weight	San Francisco Bay	Seidel et al. (1980)
		0.0004-0.002 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		0.001-0.015 mg/kg wet weight	San Diego Bay	Ishii (1982)
$MeSn^{3+}$	drinking water	0.0005-0.0081 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	< 0.00001-0.012 µg/L	Florida	Braman and Tompkins (1979)
		0.006-0.018 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-0.0016 µg/L	rivers in southeastern U.S.A.	Byrd and Andreae (1982)
		0.079 µg/L	Rhine River, Germany	Byrd and Andreae (1982)
		0.06-1.2 µg/L	rivers and lakes in Ontario	Maguire et al. (1982)
	estuarine water	< 0.00001-0.0085 µg/L	Florida	Braman and Tompkins (1979)
	sea water	< 0.00001-0.015 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.008 µg/L	California	Hodge et al. (1979)
	rain water	10 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	sea water	n.d.-42 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	sediment	n.d.-10.6 µg/kg dry weight	general	Tugrul et al. (1983)
	fish (U. mollucensis)	27 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (Patella caerulea	0.4-4.8 µg/kg dry weight	general	Tugrul et al. (1983)
	seaweed	16.8 µg/kg dry weight	general	Tugrul et al. (1983)
	rain water	0.0006-0.0022 µg/L	Florida	Braman and Tompkins (1979)
	human urine	< 0.02-0.32 µg/L	Florida	Braman and Tompkins (1979)
	shell samples	< 0.00001-0.00045 mg/kg	Florida	Braman and Tompkins (1979)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
$MeSn^{3+}$	algae	n.d.-0.004 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		n.d.-0.0012 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
Me_2Sn^{2+}	drinking water	0.0004-0.0022 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	< 0.00001-0.0075 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.063 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-0.0039 µg/L	rivers in southeastern U.S.A.	Byrd and Andreae (1982)
		0.26 µg/L	Rhine River, Germany	Byrd and Andreae (1982)
		0.00051 µg/L	Main River, Germany	Byrd and Andreae (1982)
		n.d.-0.4 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	estuarine water	0.0007-0.0046 µg/L	Florida	Braman and Tompkins (1979)
		< 0.005-0.05 µg/L	Baltimore Harbor	Jackson et al. (1982)
	sea water	0.0006-0.007 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.045 µg/L	California	Hodge et al. (1979)
	rain water	< 0.00001-0.0074 µg/L	Florida	Braman and Tompkins (1979)
	human urine	< 0.02-0.17 µg/L	Florida	Braman and Tompkins (1979)
	shell samples	< 0.00001-0.00021 mg/kg	Florida	Braman and Tompkins (1979)
	algae	n.d.-0.0022 mg/kg dry weight	San Diego Bay, California	Seidel et al. (1980)
		n.d.-0.0002 mg/kg wet weight	Mission Bay, California	Ishii (1982)
		0.0004-0.0022 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
	sea water	n.d.-45 ng/L	La Jolla, U.S.A.	Tugrul et al. (1983)
	sediment	n.d.-13.4 µg/kg dry weight	general	Tugrul et al. (1983)
	fish (U. moluccensis and M. barbatus)	~2.75 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (Patella caerulea)	0.2-18 µg/kg dry weight	general	Tugrul et al. (1983)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
Me_2Sn^{2+}	brown macroalgae	0.5 µg/kg dry weight	general	Tugrul et al. (1983)
	chlorophyta	12 µg/kg dry weight	general	Tugrul et al. (1983)
	seaweed	37 µg/kg dry weight	general	Tugrul et al. (1983)
Me_3Sn^+	drinking water	0.0005-0.0024 µg/L	Florida	Braman and Tompkins (1979)
	fresh water	< 0.00001-0.0076 µg/L	Florida	Braman and Tompkins (1979)
		n.d.-0.05 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
		n.d.-0.0023 µg/L	rivers in southeastern U.S.A.	Byrd and Andreae (1982)
		0.0022 µg/L	Rhine River, Germany	Byrd and Andreae (1982)
		0.0041 µg/L	Main River, Germany	Byrd and Andreae (1982)
	estuarine water	< 0.00001-0.004 µg/L	Florida	Braman and Thompkins (1979)
		< 0.005-0.02 µg/L	Baltimore Harbor	Jackson et al. (1982)
	sea water	< 0.00001-0.00098 µg/L	Florida	Braman and Tompkins (1979)
	rain water	< 0.00001-0.0011 µg/L	Florida	Braman and Tompkins (1979)
	human urine	< 0.02-0.13 µg/L	Florida	Braman and Tompkins (1979)
	shell samples	< 0.00001 mg/kg	Florida	Braman and Tompkins (1979)
	algae	n.d.-0.0003 mg/kg wet weight	San Diego Bay, California	Ishii (1982)
	sediment	n.d.-19.4 µg/kg dry weight	general	Tugrul et al. (1983)
	fish (U. moluccensis and M. barbatus)	~1.25 µg/kg dry weight	general	Tugrul et al. (1983)
	limpet (Patella caerulea)	0.7-63 µg/kg dry weight	general	Tugrul et al. (1983)
	brown macroalgae	5.8 µg/kg dry weight	general	Tugrul et al. (1983)
	seaweed	0.9 µg/kg dry weight	general	Tugrul et al. (1983)
Me_4Sn	estuarine water	< 0.01-0.3 µg/L	Baltimore Harbor	Jackson et al. (1982)
	invertebrates	n.d.-0.006 mg/kg	California coast	Seidel et al. (1980)
	algae	n.d.-0.012 mg/kg dry weight	San Diego Bay, California	Seidel et al. (1980)
		n.d.-0.012 mg/kg dry weight	San Francisco Bay, California	Seidel et al. (1980)
		n.d.-0.012 mg/kg wet weight	San Diego Bay, California	Ishii (1982)

TABLE 2 (Cont'd): Environmental Occurrence of Tin and Organotin Compounds

Compound	Medium	Concentration	Location	Reference
$n\text{-}BuSn^{3+}$	fresh water	0.022-1.22 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-8.5 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	estuarine water	n.d.-0.2 µg/L	Baltimore Harbor	Jackson et al. (1982)
	sediment	n.d.-0.058 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
		n.d.-0.012 mg/kg dry weight	California coast	Seidel et al. (1980)
	algae	present, but not quantitated	Mission and San Diego Bays	Ishii (1982)
$n\text{-}Bu_2Sn^{2+}$	fresh water	0.010-1.6 µg/L	Lake Michigan	Hodge et al. (1979)
		n.d.-7.3 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	fresh water surface microlayer	n.d.-2600 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	sediment	n.d.-0.35 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
$n\text{-}Bu_3Sn^{+}$	fresh water	n.d.-2.9 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	fresh water surface microlayer	n.d.-60 µg/L	lakes and rivers in Ontario	Maguire et al. (1982)
	sediment	n.d.-0.54 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
Me_2SnH_2	estuarine water	< 0.005-0.05 µg/L	Baltimore Harbor	Jackson et al. (1982)
$n\text{-}BuSnH_3$	estuarine water	0.05-0.1 µg/L	Baltimore Harbor	Jackson et al. (1982)
$n\text{-}Bu_2Me_2Sn$	sediment	n.d.-0.01 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)
$n\text{-}Bu_3MeSn$	sediment	n.d.-0.02 mg/kg dry weight	lakes and rivers in Ontario	Maguire (1984)

TABLE 3: Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Sn^{2+}	pure water	oxidation to Sn^{4+}	~2d	23°C	Fanchiang and Wood (1981)
	pure water	methylation to $MeSn^{3+}$	$\leq$1 d	anaerobic; pH 1; 1 M NaCl; 20°C; with methylcobalamin and aquocobalamin. Possible Sn^{3+} intermediate. Quantitative yield	Dizikes et al. (1978)
	pure water	methylation to $MeSn^{3+}$		aerobic; aquocobalamin not necessary	Fanchiang and Wood (1981)
	lake water/ sediment	methylation to $MeSn^{3+}$, Me_2Sn^{2+} and Me_3Sn^{+}		20°C; 10-14d; yields $\leq$ 0.004%	Chau et al. (1981)
	pure water	methylation by MeI to $MeSn^{3+}$, Me_2Sn^{2+} and Me_3Sn^{+}		19°C; 5 d; yields 0.4%	Chau et al. (1981)
Sn^{4+}	nutrient medium	bacterial production of Me_2Sn^{2+}		Me_2Sn^{2+} identification tentative; used tin-tolerant Pseudomonas strain; partially anaerobic conditions; no yield stated	Huey et al. (1974)
	nutrient medium	bacterial production of Me_4Sn and a methyltin hydride more volatile than Me_4Sn		used tin-tolerant Pseudomonas strain; aerobic; 2 weeks at 23°C; no yield stated; the Me_4Sn may have resulted from chemical decomposition of a methyltin hydride	Jackson et al. (1982)
	lake water/ sediment	methylation to $MeSn^{3+}$, Me_2Sn^{2+} and Me_3Sn^{+}		20°C; 10-14d; yield $\leq$0.008%	Chau et al. (1981)
	nutrient medium/sediment	methylation to Me_2Sn^{2+} and Me_3Sn^{+}		25°C; 14 d; positive identification, but no yields stated	Hallas et al. (1982)
$MeSn^{3+}$	lake water/ sediment	methylation to Me_2Sn^{2+}		20°C; 10-14 d; yield=2.6%	Chau et al. (1981)
	CCl_4	uv photolysis to Sn^{4+}	7 hr	$\lambda \geq 235$ nm	Blunden (1983)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Me_2Sn^{2+}	pure water	uv photolysis to Sn^{4+}	1500 hr (est.)	$\lambda \geq 200$ nm	Blunden (1983)
	lake water/ sediment	methylation to Me_3Sn^+		20°C; 10-14 d; yield=11.4%	Chau et al. (1981)
	CCl_4	uv photolysis to $MeSn^{3+}$	3 hr	$\lambda \geq 235$nm	Blunden (1983)
	pure water	uv photolysis	300 hr (est.)	$\lambda \geq 200$ nm; SnO_2 detected, but not $MeSn^{3+}$	Blunden (1983)
Me_3Sn^+	sea water/ sediment	production of Me_4Sn		2.4% yield after 80 d at 16°C; autoclaved controls also produce (less) Me_4Sn; mechanism may be disproportionation	Guard et al. (1981)
	lake water/ sediment	production of Me_4Sn		20°C; 10-14d; yield=0.0008%	Chau et al. (1981)
	lake water/ sediment	demethylation to Me_2Sn^{2+} and $MeSn^{3+}$		20°C; 10-14 d; yields 0.3% and 0.9%, respectively	Chau et al. (1981)
	CCl_4	uv photolysis to Me_2Sn^{2+}	2 hr	$\lambda \geq 235$ nm	Blunden (1983)
	pure water	uv photolysis to Me_2Sn^{2+}	30 hr	$\lambda \geq 200$ nm	Blunden (1983)
Me_3SnOH or $(Me_3Sn)_2O$	neat	reation with atmospheric CO_2		production of $(Me_3Sn)_2CO_3$ in substantial yield	Brown et al. (1972)
Et_2Sn^{2+}	pure water	persistence	2 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water	persistence	1.5 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water/mud	persistence	2.5 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Et_2Sn^{2+}	pure water	uv-photolysis	1.7 d	wavelength not stated, nor are products; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
Et_3Sn^+	fish	uptake by carp		accumulation principally in liver, brain, spinal cord, kidneys and red muscles	Stroganov et al. (1973)
	in vitro (male rat hepatocytes)	dealkylation		production of ethane and ethylene; ethylene production enhanced by pentobarbital pretreatment; no yields given, nor were organotin products specifically identified	Wiebkin et al. (1982)
	in vitro (rabbit liver microsomes) and in vivo (rats and mice)	dealkylation		15% metabolism in one hour by microsomes; 1-hydroxyethyldiethyltin, Et_2Sn^{2+} and $EtSn^{3+}$ produced	Casida et al. (1971) and Kimmel et al. (1977)
Et_3SnOH or $(Et_3Sn)_2O$	neat	reaction with atmospheric CO_2		production of $(Et_3Sn)_2CO_3$ in substantial yield	Brown et al. (1972)
Et_4Sn	rabbits (i.v. administration)	dealkylation		20% conversion to Et_3Sn^+ after 3 hr; residue levels varied in different tissues	Arakawa et al. (1981)
	rats and rabbits (by different routes of administration)	dealkylation		conversion to Et_3Sn^+ varied with organ or tissue	Iwai et al. (1982)
	in vitro (male rat hepatocytes)	dealkylation		production of ethylene and ethane; ethylene production enhanced by pentobarbital pretreatment; no yields given, nor were organotin products specifically identified	Wiebkin et al. (1982)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Et_4Sn	*in vitro* (rat liver microsomes)	dealkylation		Et_3Sn^+ and Et_2Sn^{2+} produced	Kimmel *et al.* (1977)
$n\text{-}Pr_3Sn^+$	nutrient medium	uptake by *E. coli*		uptake apparently the result of reaction with phospholipids and other phosphorus-containing compounds in cell walls	Yamada *et al.* (1978)
	in vitro (rabbit liver microsomes) and *in vivo* (rats and mice)	dealkylation		15% metabolism in one hour by microsomes; 1-hydroxypropyldipropyltin, and either $n\text{-}Pr_2Sn^{2+}$ or $n\text{-}PrSn^{3+}$ produced	Casida *et al.* (1971) and Kimmel *et al.* (1977)
$n\text{-}Pr_3SnOH$ (or $(n\text{-}Pr_3Sn)_2O$)	neat	reaction with atmospheric CO_2		production of $(n\text{-}Pr_3Sn)_2CO_3$ in substantial yield	Brown *et al.* (1972)
$n\text{-}Pr_4Sn$	rabbits (i.v. administration)	dealkylation		4% conversion to $n\text{-}Pr_3Sn^+$ after 3 hr; residue levels varied in different tissues	Arakawa *et al.* (1981)
	rats and rabbits (by different routes of administration)	dealkylation		conversion to $n\text{-}Pr_3Sn^+$ varied with organ or tissue	Iwai *et al.* (1982)
$n\text{-}BuSn^{3+}$	sea water	solubility		9-10 mg/L	Meinema *et al.* (1978)
	90% H_2O (v/v)-10% MeOH	ultraviolet spectrum		λ, nm (ε, L/mole·cm): 360 (0.07); 350 (0.08); 340 (0.10); 330 (0.23); 320 (0.54); 310 (1.21); 300 (2.38), 290 (3.53); 280 (3.73)	Maguire *et al.* (1983a)
	90% H_2O (v/v)-10% MeCN	photolysis at 300 nm	0.4 ± 0.1 d	Sn^{4+} produced in 68% yield	Maguire *et al.* (1983a)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_2Sn^{2+}$	sea water	solubility		6-8 mg/L	Meinema et al. (1978)
	90% H_2O (v/v)-10% MeOH	ultraviolet spectrum		λ, nm (ε, L/mole•cm): 360 (0.03); 350 (0.04); 340 (0.05); 330 (0.06); 320 (0.07); 310 (0.10); 300 (0.16); 290 (0.29); 280 (0.75)	Maguire et al. (1983a)
	90% H_2O (v/v)-10% MeCN	photolysis at 300 nm	> 9 d	small amount of $BuSn^{3+}$ and Sn^{4+} produced	Maguire et al. (1983a)
	12% HCl	photolysis	< 1 hr	wavelength not stated; dealkylation eventually to Sn^{4+}	Woggon and Jehle (1975)
	pure water	persistence	1.1 d	products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water	persistence	1.6 d	products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water/mud	persistence	1.1 d	products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water/sand	persistence	1.3 d	products not stated; reaction is described without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pure water	uv-photolysis	0.8 d	wavelength not stated, nor are product; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_2Sn^{2+}$	*in vitro* (rat liver microsomes) and *in vivo* (mice)	dealkylation		$BuSn^{3+}$ was major product	Kimmel *et al.* (1977)
	fungal culture medium	dealkylation	~14 d	$BuSn^{3+}$ identified as product upon aerobic incubation of *Coniophora puteana* ; 30°C	Barug (1981)
	solutions of reducing sugars in phosphate buffers	dealkylation	~1 d	$BuSn^{3+}$ major product	Barug (1981)
	lake water/ sediment	production of Me_3Sn^+		20°C; 10-14 d; yield 0.002%	Chau *et al.* (1981)
$n\text{-}Bu_2Sn\text{-}(SCH_2CO_2C_8H_{17})_2$	incorporated in polyvinyl chloride	photolysis in "artificial sunlight"		converted to $n\text{-}Bu_2SnCl\text{-}(SCH_2CO_2C_8H_{17})$ after 17 d; prolonged irradiation led to formation of $SnOCl_2$	Brooks *et al.* (1982)
$n\text{-}Bu_3Sn^+$	pure water	log K_{ow}		3.2 at pH 6 and 20°C	Maguire *et al.* (1983a)
	pure water	adsorption to glass and Teflon		significant below 2 mg/L	Maguire *et al.* (1983a)
	pure water	volatilization		none over 62 d at 20°C	Maguire *et al.* (1983a)
	pure water	stability in dark		no loss of butyl groups from tin over 63 d at 20°C between pH 2.9 and 10.3	Maguire *et al.* (1983a)
	90% H_2O (v/v)-10% MeOH	ultraviolet spectrum		λ, nm (ε, L/mole·cm): 360 (0.06); 350 (0.10); 340 (0.16); 330 (0.26), 320 (0.40); 310 (0.64); 300 (0.98); 290 (1.62); 280 (2.72)	Maguire *et al.* (1983a)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_3Sn^+$	pure water	photolysis at 300 nm	1.1 ± 0.2 d	products: Bu_2Sn^{2+}, $BuSn^{3+}$ and Sn^{4+}; product yield ~50%	Maguire et al. (1983a)
	pure water	photolysis at 300 nm, sensitized with 15 mg/L fulvic acid	0.6 ± 0.2 d		Maguire et al. (1983a)
	pure water	photolysis at 350 nm	>18 d		Maguire et al. (1983a)
	pure water	photolysis at 350 nm, sensitized with 15 mg/L fulvic acid	6.2 ± 1.8 d		Maguire et al. (1983a)
	fresh water or distilled water	sunlight photolysis	> 89 d (>4×10^4 langleys)	small amounts of Bu_2Sn^{2+}, $BuSn^{3+}$ and Sn^{4+} formed	Maguire et al. (1983a)
	12% HCl	photolysis	< 1 hr	wavelength not stated; dealkylation eventually to Sn^{4+}	Woggon and Jehle (1975)
	plant surfaces	photolysis	~4 hr	Bu_2Sn^{2+}, $BuSn^{3+}$ and Sn^{4+} produced; wavelength not stated	Woggon and Jehle (1975)
	12% HCl	dealkylation		solution boiled; no product yield or kinetics given	Woggon and Jehle (1975)
	pure water	reaction with MeI		19°C; 5 d; products were $MeSn^{3+}$ (8×10^{-5} %), Me_2Sn^{2+} (2×10^{-5} %) and Me_3Sn^+ (8×10^{-5} %)	Chau et al. (1981)
	pure water	persistence	19 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_3Sn^+$	tap water	chemical stability	> 16 d	chemical stability was defined as the length of time its molluscicidal activity remained unchanged when dissolved in tap water at a concentration close to the LC_{90}^{24h} value for (unidentified) snails. The container used was made of wax-lined paper.	Ritchie and Berrois-Duran (1969)
	fresh water	stability	> 3 months		Woggon and Jehle (1975)
	sea water	reaction with CO_2 to form $(Bu_3Sn)_2CO_3$		claim made with no supporting evidence on yield or kinetics; no references given	Sheldon (1975)
	pond water	persistence	10.5 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	pond water/sand	persistence	3.8 d	products not stated; reaction is described, without elaboration, as "hydrolysis"	Mazayev et al. (1976)
	in paint chips from ships' hulls which have been sand-blasted	thermal decomposition to Sn^{4+}		kiln temperatures > 625°C were effective	Schatzberg and Harris (1978)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_3Sn^+$	fresh water and seawater (pH 5-9)	stability in dark		little or no loss of butyl groups from tin over 35 d. Solubility limit exceeded in some tests. Possibility of adsorption to glass container walls	Slesinger and Dressler (1978)
	water	photolysis under General Electric F40BL fluorescent lights	18.5 d (TBTO) 2 d (TBTF)	half-life varied with source of $n\text{-}Bu_3Sn^+$, and was considerably shorter in the presence of acetone photosensitizer; the light source used approximates the spectral distribution of sunlight, but the relative intensities are unknown	Slesinger and Dressler (1978)
	lake water/ sediment	production of Me_3Sn^+		20°C; 10-14 d, yield 0.002%	Chau et al. (1981)
	soil	dealkylation (aerobic)	15-20 weeks	20°C in the dark; $^{14}CO_2$ and Bu_2Sn^{2+} among products; considerable formation of unextractable residues	Barug and Vonk (1980)
	soil (clay, sand and top soil)	leaching from soil		little leaching after 16 weeks (1 inch of rain per week); little experimental detail given	Schatzberg and Harris (1978)
	soil	leaching from soil	> 180 d	25°C; substantial production of Bu_2Sn^{2+} and $BuSn^{3+}$. Substantial unextractable residue	Sheldon (1978)
	soil	dissipation (aerobic)	~60 d	combination of (at least) dealkylation and formation of unextractable residues	Sheldon (1978)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_3Sn^+$	soil	dealkylation (anaerobic)	> 180 d	25°C; substantial production of Bu_2Sn^{2+} and $BuSn^{3+}$. Substantial unextractable residue.	Sheldon (1978)
	soil	dissipation (anaerobic)	> 200 d	combination of (at least) dealkylation and formation of unextractable residues	Sheldon (1978)
	impregnated in wood posts	mobility in terrestrial microcosm		93.6% ^{14}C radiolabel retained in wood, 4.5% in surrounding soil, indicating very little migration after 2.5 months. Earthworms accumulated 7.9 mg/kg from the soil, indicating that soil-associated residues were not biologically unavailable; however, no evidence presented to show that the radiolabel is unequivocably Bu_3Sn^+	Glie *et al.* (1982
	culture medium	dealkylation	5-10 d	*Pseudomonas aeruginosa* in aerobic medium degraded Bu_3Sn^+ to $BuSn^{3+}$; no Bu_2Sn^{2+} detected, perhaps because Bu_2Sn^{2+} was quickly converted to $BuSn^{3+}$ by reducing sugars in phosphate buffer	Barug (1981)
	culture medium	dealkylation	3-4 d	*Coniothora puteana* in aerobic medium effects the transformation $Bu_3Sn^+ \rightarrow Bu_2Sn^{2+} \rightarrow BuSn^{3+}$	Barug (1981)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu_3Sn^+	culture medium	uptake by estuarine bacteria		Bu_3Sn^+ accumulated to 3.7-7.7 mg Sn/g dry weight of cells, probably by simple adsorption to cell walls; no dealkylation noted	Blair *et al.* (1982)
	culture medium	accumulation and dealkylation by a green alga	4 weeks	*Ankistrodesmus falcatus* had a maximum apparent algal bioconcentration factor of 3×10^4; over 4 weeks at 20°C, 50% of the original Bu_3Sn^+ was converted to Bu_2Sn^{2+} and small quantities of $BuSn^{3+}$ and Sn^{4+}	Maguire *et al.* (1983b)
	in vitro (rabbit liver microsomes) and *in vivo* (rats and mice)	dealkylation		15% metabolism in one hour by microsomes; 1-hydroxybutyldibutyltin produced along with a tributyltin compound having 1 or 2 hydroxyl groups not at the 1-position, and 3 unidentified debutylated metabolites	Casida *et al.* (1971)
	in vitro (rat liver microsomes) and *in vivo* (mice)	dealkylation		initial products were α, β, γ- and δ-hydroxybutyldibutyltin, and γ-ketobutyldibutyltin. The δ- (24%) and β-hydroxy (50%) products predominated, but were unstable in neutral or acidic solution, yielding 1-butanol and 1-butene, respectively, with concomitant formation of Bu_2Sn^{2+}	Fish *et al.* (1976) and Kimmel *et al.* (1977)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-}Bu_3Sn^+$	sheepshead minnow (*Cyprinodon variegatus*)	uptake and dealkylation		maximum observed bioconcentration facor for whole fish was 2.6×10^3. Depuration "first half-life" was 7d. Metabolism to Bu_2Sn^{2+}, $BuSn^{3+}$ and Sn^{4+}	Ward *et al.* (1981)
$n\text{-}Bu_3SnOH$ or $(n\text{-}Bu_3Sn)_2O$	neat	reaction with atmospheric CO_2		production of $(n\text{-}Bu_3Sn)_2CO_3$ in substantial yield	Brown *et al.* (1972)
$(n\text{-}Bu_3Sn)_2O$	adsorbed on cellulosic materials	reaction with atmospheric CO_2		production of $(n\text{-}Bu_3Sn)_2CO_3$	Smith *et al.* (1977)
	sea water	solubility		8-10 mg/L	Meinema *et al.* (1978)
	pure water	solubility		0.7-7 mg/L at 20°C and pH 5-7, increasing with both increasing and decreasing pH	Maguire *et al.* (1983a)
	neat	vapour pressure		6.7×10^{-7} mm Hg at 20°C; estimated by a kinetic comparative technique	Maguire *et al.* (1983a)
	neat	uv photolysis		wavelength not stated; irradiation for 24 hr at 24°C; products were 1-butene and traces of polymeric Bu_2SnO and aldehydes	Komoro and Popl (1978)
$n\text{-}Bu_4Sn$	rabbits (i.v. administration)	dealkylation		1% conversion to $n\text{-}Bu_3Sn^+$ after 3 hr; residue levels varied in different tissues	Arakawa *et al.* (1981)
	rats and rabbits (by different routes of administration)			conversion to $n\text{-}Bu_3Sn^+$ varied with organ or tissue	Iwai *et al.* (1982)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
n-Bu_4Sn	in vitro (rat liver microsomes)	dealkylation		8 metabolites, including (β-HOBu) Bu_3Sn, (γ-HOBu)-Bu_3Sn and all products detected with Bu_3Sn^+ as substrate (see above) except (γ-C=O-Bu)Bu_2Sn^+	Kimmel et al. (1977)
n-Pen_3Sn^+	in vitro (rabbit liver microsomes) and in vivo (rats and mice)	dealkylation		metabolism slower than analogous Et, Pr and Bu compounds; 10 metabolites detected, including (probably) (α-HOPen)Pen_2Sn^+, 2 other acid-labile Pe_3Sn^+ metabolites, 2 acid-stable Pe_3Sn^+ metabolites, and 5 Pen_2Sn^{2+} and $PenSn^{3+}$ metabolites	Casida et al. (1971)
	in vitro (rabbit liver microsomes)	dealkylation		of the 10 metabolites (see above), Pen_2Sn^{2+} and (β-HOPen)Pen_2Sn^+ were major metabolites	Kimmel et al. (1977)
n-Hex_3Sn^+	in vitro (rabbit liver microsomes) and in vivo (rats and mice)	dealkylation		metabolism slower than Pen_3Sn^+; 5 metabolites detected, including (probably) (γ-HOHex)Hex_2Sn^+, 2 acid-stable Hex_3Sn^+ metabolites, and 2 Hex_2Sn^{2+} and $HexSn^{3+}$ metabolites	Casida et al. (1971)
	in vitro (rabbit liver microsomes)	dealkylation		of the 5 metabolites (see above), Hex_2Sn^{2+} and (β-HOHex)Hex_2Sn^+ were major metabolites	Kimmel et al. (1977)
n-Oct_2Sn^{2+}	pure water	persistence	3.2 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev et al. (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$n\text{-Oct}_2Sn^{2+}$	pond water	persistence	6.2 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev *et al.* (1976)
	pond water/mud	persistence	1.9 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev *et al.* (1976)
	pond water/ sand	persistence	4.7 d	products not stated; reaction is described, without elaboration as "hydrolysis"	Mazayev *et al.* (1976)
$nOct_3Sn^{+}$	*in vitro* (rabbit liver microsomes)	dealkylation		metabolism very much slower than $n\text{-Hex}_3Sn^{+}$; only trace amounts of $n\text{-Oct}_2Sn^{2+}$ detected as metabolite	Kimmel *et al.* (1977)
$CySn^{3+}$	water	photolysis		wavelength not stated; cyclohexanone and cyclohexanol were prominent products	Casida *et al.* (1971)
Cy_2Sn^{2+}	water	photolysis		wavelength not stated; cydohexanone and cyclohexanol were prominent products	Casida *et al.* (1971)
	in vitro (rabbit liver microsomes) and *in vivo* (rats and mice)	dealkylation		major products were $CySn^{3+}$ cyclohexanone and cyclohexanol	Casida *et al.* (1971) and Kimmel *et al.* (1977)
	(as Cy_2SnO), on glass plates	volatilization		10% loss over 100 days	Smith *et al.* (1976)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Cy_3Sn^+	*in vitro* (rabbit liver microsomes) and *in vivo* (rats and mice)			rate of metabolism intermediate between n-Pen_3Sn^+ and n-Hex_3Sn^+; 7 metabolites-2 acid-labile, 3 acid-stable and 2 Cy_2Sn^{2+} and/or $CySn^{3+}$ metabolites	Casida *et al.* (1971)
	water	photolysis		wavelength not stated; cyclohexane and cyclohexanol were prominent products	Casida *et al.* (1971)
	on apples and pears	persistence	< 5 weeks	products were Cy_2Sn^{2+}, $CySn^{3+}$ and Sn^{4+}; some loss by rain; very little translocation of residue from surface to the insides of apples and pears	Getzendaner and Corbin (1972)
	soil	dealkylation		orchards treated with Plictran for up to 3 years had residues consisting of 80% Cy_3Sn^+, 14% Cy_2Sn^{2+} and 6% $CySn^{3+}$; there was little leaching from soil since the residue was found almost entirely in the 0-15 cm layer	Blair (1975)
	in vitro (rabbit liver microsomes)			products were (2-HOCy)Cy_2Sn^+ (tentative), Cy_2Sn^{2+} (major), 3 acid-stable Cy_3Sn^+ derivatives (possibly hydroxylated at 3 or 4 position)	Kimmel *et al.* (1977)
	in vitro (rabbit liver microsomes)			in addition to products shown above, futher evidence for (3-HOCy)Cy_2Sn^+ and (4-HOCy)Cy_2Sn^+	Kimmel *et al.* (1980)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Cy_3Sn^+	on glass plates and on "apple wax"	photolysis	~8 hr	corresponds roughly to 8 d irradiation in a sunny climate. Reaction pathway appears to be by sequential dealkylation; 80% conversion to Sn^{4+} over 32 d	Smith et al. (1976)
	neat (as Cy_3SnOH), on glass plates	volatilization		none over 100 d	Smith et al. (1976)
	pure water	volatilization		evidence for "co-distillation" with water	Smith et al. (1976)
$PhSn^{3+}$	water	stability	several minutes	at $[PhSn^{3+}]_0 \geq$ 4mg/L, 80-90% recovery of Sn^{4+}; at $[PhSn^{3+}]_0 \leq$ 0.1 mg/L, Sn^{4+} accounted for only 10% of the products; evidence for production of water-soluble polymeric tin species	Soderquist and Crosby (1978)
Ph_2Sn^{2+}	water	stability	2-3 d	21°C, pH 5.5-8.5; no $PhSn^{3+}$ or Sn^{4+} produced - no wall adsorption	Soderquist and Crosby (1980)
	5% aqueous acetone	sensitized sunlight photolysis	~5 hr	acetone photosentizer; the dark control was also unstable (see above); evidence for production of water-soluble polymeric tin species	Soderquist and Crosby (1980)
Ph_3Sn^+	glass plate	u.v. photolysis		products were Ph_2Sn^{2+}, $PhSn^{3+}$ and Sn^{4+}	Chapman and Price (1972)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Ph_3Sn^+	soil	binding		strong binding indicated by 50% decrease in extractability over 40 days from sterile or non-sterile soil. Little leaching from soil with water	Barnes et al. (1973)
	silica gel plates	u.v. photolysis		$\lambda \geq 254$ nm; degradation to Sn^{4+} via Ph_2Sn^{2+} and $PhSn^{3+}$	Barnes et al. (1973)
	soil	degradation	~140 d	50% of ^{14}C label evolved as $^{14}CO_2$ over 140 d from non-sterile soil	Barnes et al. (1973)
	culture medium	degradation		$^{14}CO_2$ released by Aspergillus sp., conidia and a Gram-negative bacterium	Barnes et al. (1973)
	on sugar beet leaves exposed to sunlight but protected from rain	dealkylation	~14 d	production of Ph_2Sn^{2+}, $PhSn^{3+}$ and Sn^{4+}; significant amounts of unextractable ^{113}Sn residue	Freitag and Bock (1974b)
	rats (by stomach tube)	dealkylation		substantial amounts of Ph_2Sn^{2+}, $PhSn^{3+}$ and Sn^{4+} excreted	Freitag and Bock (1974b)
	12% HCl	u.v. photolysis	< 10 min	wavelength not stated; dealkylation eventually to Sn^{4+}	Woggon and Jehle (1975)
	rats (oral or i.p. administration)	dealkylation		substantial amounts of Ph_2Sn^{2+}, $PhSn^{3+}$ and Sn^{4+} excreted; large amounts of unextractable ^{113}Sn residue in feces; no metabolism by rabbit liver microsomes	Casida et al. (1977)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
Ph_3Sn^+	soil	persistence	1 d	first half-life 1 day, second half-life ~6 d; no products identified; may simply have been observing strong binding to soil	Kuwahara *et al.* (1980)
	lake water/ sediment	production of Me_3Sn^+		20°C; 10-14 d; yield 0.002%	Chau *et al.* (1981)
	fresh water and sea water (pH 5-9)	stability in dark		no loss of Ph_3Sn^+ over 35 d at pH 5-7 and in sea water; 43% loss at pH 9	Siesinger and Dressler (1978)
	water	photolysis under General Electric F40BL fluorescent lights	54 d	$t_{\frac{1}{2}}$=12.5 d in presence of acetone photosensitizer; the light source used approximates the spectral distribution of sunlight, but the relative intensities are unknown	Siesinger and Dressler (1978)
	water	stability		no loss of Ph_3Sn^+ over 30 d at pH 4.2-10.0 and 21-32°C	Soderquist and Crosby (1980)
	water	volatilization		none over 6 d at 32°C even though the water loss from the test beakers was 55 mL/ day	Soderquist and Crosby (1980)
	water	photolysis (sunlight)	14-21 d	pH 7.2; similar results with a laboratory photoreactor (λ>290 nm, $t_{\frac{1}{2}}$~14 d); the photolysis was accelerated considerably by acetone and rose bengal ($t_{\frac{1}{2}}$<1d), but not by filtered rice-field water; evidence for mechanism featuring production of Ph_2Sn^+ accompanied by further formation of water-soluble polymeric tin species	Soderquist and Crosby (1980)

TABLE 3 (Cont'd): Properties and Transformations of Inorganic Tin and Organotin Compounds Relevant to Environmental Fate

Compound	Medium	Transformation/Property	Half Life	Comments	Reference
$CyPh_2Sn^+$	*in vitro* (rat liver microsomes)	hydroxylation		trans-2-$HOCyPh_2Sn^+$ was major product; also produced were 3- and 4-$HOCyPh_2Sn^+$. No metabolism involving phenyl groups	Kimmel *et al.* (1980)
$CyPh_3Sn$	*in vitro* (rat liver microsomes)	hydroxylation		major product (85.6%) was trans-4-$HOCyPh_3Sn$; also formed were cis-3-$HOCyPh_3Sn$ (6.5%), trans-3-$HOCyPh_3Sn$ (30%), trans-2-$HOCyPh_3Sn$ (1.6%), 4-keto$CyPh_3Sn$ (1.9%) and 3-keto$CyPh_3Sn$ (1.4%). The trans-2HO metabolite undergoes 1,2-deoxystannylation in acid to yield Ph_3Sn^+ and cyclohexene	Fish *et al.* (1977)